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THE PRESENT STATUS OF THE PEAT-FUEL INDUSTRY IN THE UNITED STATES.*

By A. Frederick Collins.

What with the recent address of President Roosevelt to the Pennsylvania miners, the concealment by the Coal Trust of thousands of tons of anthracite, and the statement of John Mitchell to the effect that unless the demands of his union are complied with a strike will take place in the spring, it is small wonder that the consumers of this commodity at large are sore afraid they will run amuck of another fuel famine.

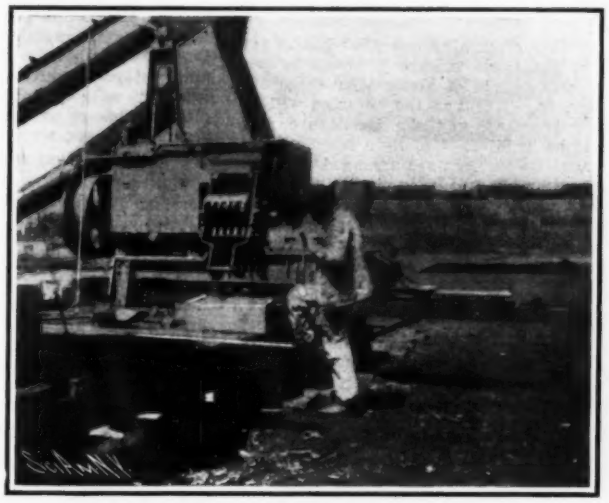
The price of anthracite coal, as all who burn this commodity must know, is now steadily rising, and the chances of the usual spring reduction of 50 cents a ton, in consequence of the operators having advanced the price per ton ten cents on five different occasions, practically *nil*, while the reduction of 65 cents by the retailers has been wiped out by four advances, so that as the market now stands it is delivered by the operators free on board at $5 per ton, while the quotation of the retailers is $6.25.

Under these circumstances, then, it is well to direct public attention to a new fuel plant that has taken root and is now being carefully watched by experts as well as the coal barons at New Rochelle, N. Y. This is the equipment of the Peat-Koal Company, installed a year or so ago under the direction of Mr. H. H. Wotherspoon, Jr., the well-known fuel engineer. While peat and peat-coal plants are by no means novel, the one under consideration is the first and only one of its kind in America, and its success is due to a number of vital factors that seem to have been entirely overlooked by those who have attempted to enter this field in the past.

What it is that makes for success in the present venture, and why it is that failure has resulted in prior attempts, will be realized when the nature of peat is understood. What is termed peat is simply a substance formed by the partly decomposed vegetable material in the presence of water. The plants may grow profusely on top of the bog, but as these succumb to the elements they are submerged; and as this process takes place rapidly, peat is produced, varying from one to five inches a year, until the depth of the bed may range from 10 to 40 feet.

While peat beds are found in the northern and southern temperate zones, they occur most frequently in the former, especially where sphagnum mosses grow. In the tropics such bogs are not found, for the reason that the vegetable material decomposes too quickly to permit it to properly carbonize. Throughout the temperate regions of the north, where the conditions are conducive to the formation of peat, as in Great Britain and Continental Europe, there are millions of acres, while in Canada and the United States there are even larger deposits.

In Europe, especially in those countries where there is little or no coal to be mined, and wood is likewise an expensive commodity, these beds have been operated systematically for many years as an all-around fuel. Many attempts have been made in America to manufacture compressed peat briquettes, but this method has in every instance proven unsuccessful, since coal under normal conditions is comparatively



SIDE VIEW OF THE BRIQUETTING MACHINE.

FRONT VIEW OF THE BRIQUETTING MACHINE, SHOWING DIE WHERE THE BLOCKS ARE FORMED.

CONVEYING PEAT FROM THE BOG TO THE MACHINE WHERE IT IS BRIQUETTED.

DUMPING THE BRIQUETTES ON THE GROUND TO DRY.

THE BRIQUETTES AS THEY ISSUE FROM THE MACHINE.

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*Specially prepared for the Scientific American Supplement.

cheap, and any process of peat-fuel making that utilizes more than ordinary pressure or employs heat to eliminate the water and render the block more compact, must of necessity fail, for in these lie the prohibitive sources of expense.

In Holland, Germany, and other foreign countries where the most successful peat plants in the world are in operation, these untoward features have long ago been cast out, and the simplest method has been found not only the cheapest, but the best as well. This plan has just been introduced into this country by Mr. H. H. Wotherspoon, Jr., the peat-fuel engineer, after an exhaustive study of the situation abroad.

First as to the nature of peat and its environments. In a good bog the carbonized material is very black and dense immediately under the surface. As there are considerable quantities of tannic and other acids, various salts and iron in the deposits, all of which have a tendency to preserve the vegetable matter, the beds are practically valueless for farming; but oppositely disposed, the excellent condition of the fibers of the plants has led to experiments looking toward the use of peat in the textile industries. Thus far such investigations have not worked out commercially, and hence the only value of such land is for the making of fuel.

When vegetation such as grasses, shrubs, and mosses is exposed to the effects of the elements, they give off their gases very quickly, nitrogen in the largest amount, some hydrogen, and a little oxygen; whereas if the plants above named are inundated with stagnant water, the only gas that is liberated is marsh gas, a stable colorless compound formed by one atom of carbon and four atoms of hydrogen. The proportion of carbon in the peat thus lost is exceedingly small, and thus the greater amount of this valuable element, which is the portion required for burning, is stored up for future use.

Peat beds then may be looked for wherever there are swamps or other poorly drained land, and the decomposed matter forms in a literal sense a vein of coal in the early stages of making. Although decomposed, the plants retain to a considerable extent their fibrous qualities, and these absorb large amounts of water. By the chemical action that takes place, a peculiar adhesive property is evolved, and it is this principle that plays so important a part in the making of peat fuel. This substance is as sticky as glue, and is known technically as pentazone.

To pentazone is due in no small measure much of the ill success that has attended the different processes utilizing furnaces as a means for expelling the moisture from the freshly briquetted product, for the moment heat is applied in excess of 100 deg. Fahrenheit, it loses its value as a binder, and hence high temperatures are not only expensive but destructive. Permitted to dry in the open air and under the gentle influence of the sun, the pentazone quickly hardens, when the particles of peat are rigidly bound together.

The first plant to be operated in this country wherein the above conditions have been rigorously observed is at New Rochelle, N. Y., where the Peat-Koal Company is now commercially converting the black mud into good fuel by a process that is at once efficient, simple, and cheap. Here the peat as it is dug from the bog is carried by an endless belt conveyor to a reduction machine, which will presently be described in detail, and wherein three different operations take place, that is, it breaks up the decomposed mass, then tears asunder the tube-like structure of the plants which frees the pentazone, and lastly works over the material, when 15 per cent of the water it contains is removed, after which the green fuel is forced from the machine.

As the peat continually emerges it is cut off into desirable lengths, and then spread out in the open on the ground. Whatever water now remains is evaporated slowly and naturally by the sun and air, a process requiring from fifteen to twenty days; the drying is naturally attended by shrinkage in weight and volume, but the final result is a black, brittle, and compact mass having nearly the specific gravity of bituminous coal, but which is as smokeless as coke and is equally as hot as anthracite.

The new plant is located near the tracks of the Harlem division of the New York, New Haven & Hartford Railroad, where the company owns and controls 25 acres of bog land that has heretofore been deemed valueless; yet according to Mr. Wotherspoon its quality is superior to the best that Germany has to offer. Tests have shown that the bog has an average depth of about 25 feet, while at the center it has a maximum depth of approximately 40 feet.

To prepare the bog for excavating, the growth of vegetation was plowed up, and then it was drained by a series of ditches leading to a common center, where the water is forced out by means of a small centrifugal pump driven by a kerosene engine, whence it is conveyed to a nearby stream.

That the element of uncertainty might not enter into the introduction of peat-fuel making in this country, the most successful device, and one that has been in operation for the past twenty-five years in Germany, was brought over and installed; this is the simple but powerful machine of Schlickeysen. The machine is fed by men who shovel the peat into a trough conveyor, which connects the hopper with the pit; the machine proper comprises three distinct elements, namely, a disintegrator, a reduction mill, and a rotating screw, the latter delivering the soft cohering mass through an orifice or die having three separate, parallel, and longitudinal divisions.

As the freshly-formed square layers of pulp issue forth they are run out on individual boards, each capable of holding 12 briquettes, where they are cut into blocks about 12 inches in length. The boards with the blocks upon them are carried to small industrial cars, the last named being pushed by hand around the yard to convenient points for drying when they are dumped.

The mill weighs three tons, and contains all the latest improvements, such as ejectors for throwing out stones and other foreign substances before they can reach the disintegrating beaters or the reduction knives. A 15-horse-power kerosene engine drives the machine, and this is much more economical than a steam engine, for no licensed engineer is needed, and the kerosene consumed during a run of ten hours amounts to only $1.75. Both engine and mill are mounted on the same platform, thus forming a compact unit; the platform rests on a track, and by this arrangement they may be easily moved along the pit as the work progresses.

The workmen dig out, from one side to the other of the bog, a pit that measures 20 feet wide, but when the peat is removed to a depth of 5 feet, another pit of a similar width and depth will be cut, and so on until the entire bog has been excavated. When this is done, the operation is begun all over again, and this may be repeated twice or thrice or until the peat has been exhausted.

The mill is capable of turning out 6,500 blocks per hour; of the weight these represent, about 85 per cent is water. In a couple of hours after these are spread out to dry, 10 per cent of the moisture will be found to have evaporated, and the blocks are now strong enough to be handled. Usually a few days are permitted to elapse before they are arranged in small loose piles, so that the air can freely circulate through them, and in another two hours an additional 10 per cent of the water contained is lost. As the drying goes on, more time is required for its final elimination. If the days are dry and the sun shines brightly, fifteen days may suffice to render them fit for fuel, otherwise eighteen or twenty days will be required.

It is obviously clear that where compression is not attempted, and where nature is made to do the work instead, there is a large saving effected as against those processes where it is a factor. It is likewise obviously true that the process under consideration requires a considerable length of time, but this is of no particular moment, for the bog itself offers ideal conditions for spreading out and drying hundreds of tons of the briquettes. The advantages of this mode of procedure may be restated by saying that where compression is resorted to, the peat is pressed into layers, and a brick so produced has not nearly the enduring qualities of the brick obtained by the contraction of its fibers through the agency of time and the elements.

As the blocks come from the mill they weigh about 6 pounds and have a volume of 120 cubic inches, but after the water has been evaporated they are reduced in size until they weigh 1.3 pounds and have a volume of 24 cubic inches. In a brick that is ready to burn there still remains 12 per cent of water, but this is chemically combined with the other ingredients. As this percentage may vary, it has been suggested that it should be sold by cubic measure instead of by weight, and in small lots this is done.

It will readily be seen that the expense of operation is reduced to a minimum, and the appended figures will offer additional light on the subject. To the present time 25 men have been at work in this primitive, yet paradoxical, up-to-date coal mine. The output is between 30 and 35 tons per day, and the cost of production ranges from $1.50 to $1.75 per ton.

This bog product has been called an emergency fuel; but when it is considered that four pieces of peat coal weighing one pound each will cook a breakfast for four people at a total cost of 12 mills, and that there are peat bogs everywhere, it indicates that this is the natural fuel, and as such it will supplant bituminous and anthracite unless the competition of the former knocks the pedestal from under the coal barons, and they reduce the price to a marked degree.

It may be asked what becomes of the plant when the bog is exhausted. One of the advantages of a peat plant of this character is that it requires no permanent fixtures. The machinery is easily moved, and the few buildings that are required are of the "knock-down" type, that is they can be put up or taken apart without the use of a nail. While the work is in progress the bog is of course drained, but when all the peat is removed, the water is permitted to flow in, filling the hole, a small artificial lake is made, and ice cutting furnishes another enterprise.

The mills may be had in all sizes, capable of turning out, from No. 3, 35 tons per day, and every farmer can have his own coal mine and his own ice plant, just as he has his own power and his own garden. This and the cheapness of the product are reasons why it is likely that the peat industry will prove a formidable rival to the coal trust.

Coal mines are localized in a few districts throughout the country, and the properties are not only of exceeding value, but the monopolists have them all securely within the hollow of their hands, as well as the carriers which transport this commodity; but since peat bogs are everywhere, machines are readily available, and the operation of such plants requires no skilled labor; certainly communities, however large or small, will not be coerced always into paying high prices for coal, with occasional extraordinary prices during those periods when men at the mines are fighting for their very lives.

There are twenty-five million tons of bog fuel within a radius of ten miles from New York city, and this gigantic deposit, as we have seen, may be transformed to fuel for $1.75 per ton, and probably much cheaper. In every section of the country there are dormant wastes of rich peat beds of exceeding value, though they are worth nothing as they now stand. The grass meadows and swamps of this country are mines as rich as those in the gold fields of the Klondike, and are capable of being converted into light, heat, and power, with by-products of great importance.

OTTER FURS.*

By CHARLES H. STEVENSON.

THE fur of the otter is short, abundant, and of fine quality. It is slightly waved and silky and is similar in appearance to that of the beaver, but is somewhat shorter and more delicate and glossy. The fur on the stout tail is of the same character as that on the body, but not so long. That on the body is of a whitish-gray for two-thirds of its length from the base, rich brown at the tips, and is interspersed with stiff, thick overhairs similarly colored. The general color of the overhairs is brown above and a little whiter beneath, with chin and throat whitish. The shade of brown varies according to the locality in which the animal lives; in eastern Maine this is almost black; in Canada, Nova Scotia, and Labrador it is dark brown; in Alaska and British Columbia the animal is light brown. The fur on the throat, under parts, and inner surface of the legs is usually of various shades of brown. White or albino skins are occasionally secured, and silvery, grizzly, mottled, and slate-colored are met with at times.

TRADE IN OTTER SKINS.

The early trade in otter skins in America, although never so extensive, was almost contemporaneous in its development with the trade in beaver furs. In the operations of the early fur-traders in the present limits of the United States many otters were obtained. It appears, however, that the capture of these was merely incidental to the taking of beaver. Indeed, during the first hundred years of the exploitation of America the beaver was almost the only fur-bearing animal whose capture was a special object of industry. Later, however, with the increase in value of the pelts, the otter became an object of special pursuit, and by 1777 the industry reached an extent from which it has varied little up to the present time.

It is quite remarkable that the number of otter skins which are handled annually at the London sales should have fluctuated so little during the last 140 years. From 1763 to 1900 the annual quantity exceeded 30,000 only twice, and it fell short of 8,000 the same number of times, and the average by decades is nearly the same throughout the last 120 years.

With the exception of nutria, a smaller proportion of the total product of otter skins are now handled at the London sales than in case of any other aquatic fur, only about one-third of the American product being sold there. The others are sold at Leipsic or directly to the furriers of the United States and Canada. The best local markets for otters are in Russia and Greece, where the fur is much used for caps, collars, and trimmings.

Out of a total of 7,865 otter skins sold in London in March, 1901, 3,293 were No. 1; 2,498 were No. 2; 1,318 were No. 3, and 756 were cubs. The No. 1 averaged in value 28s. 6d.; the No. 2, 20s. 6d.; the No. 3, 12s. 1d., and the cubs 5s. 6d. per skin. These prices were somewhat less than the average in 1900. The highest price secured at the 1901 sale was 115s. each for a lot of 42 skins, while the lowest price was 3s. each for a lot of cubs, and also for a number of part pale No. 3. Exclusive of the cubs, those of a brown color numbered 269, while 301 were partly brown, 693 pale, 1,691 partly pale, and the remaining 4,155 of the distinctive dark otter color.

DRESSING OTTER SKINS.

When received at the fur-dresser's, otter skins are almost invariably cased, and are first cut open longitudinally down the chest and abdomen. The pelt is soaked in salt water over night for the purpose of softening it and preparing it for "breaking." The following morning each skin is placed on a beam, and a workman proceeds to break up the grain of the membrane. The pelt is now washed in warm soap water and the water removed, as in the case of beaver skins. If the overhairs are to be plucked, that is done next. The choicest skins are left "in the hair," the number amounting to about a third of the total quantity dressed.

The pelt, which has become less bulky and quite soft from frequent handling, is now placed on a beam and skived. It is next dampened with cold salt water and allowed to thus remain over night. The next morning it is stretched lengthways and crossways and partly dried, when it is ready for the leathering process. It is well rubbed with butter, or some other animal grease, and placed with others in a tramping machine, where it is worked for hours. On removal the skins are revolved for three or four hours with a quantity of hard-wood sawdust in a cleaning drum, under which there is steam heat or a charcoal fire. Next they are placed in tubs with a quantity of sawdust, where they are tramped for about three hours by barefooted workmen and on removal are thoroughly stretched. The leather side of the pelts is dampened over night and then shaved down to a uniform thickness as in case of beaver skins. A skillful workman can shave thirty or forty otter pelts in a day. The skins are then

* From U. S. Fish Commission Report.

stretched, dried, and placed for a second time in tubs with hard-wood sawdust and tramped for two or three hours, then removed, stretched again, and returned for two or three hours' further tramping, and then the fur is straightened out with a fine steel comb. The skins now receive a thorough beating with rattans to remove every vestige of sawdust and to lighten up the fur. If they have been unhaired, they go to the workman who removes all scattering hairs by means of a broad-bladed knife.

The methods of dressing otter furs have been greatly improved in this country in recent years, and the reputation of American workmen in this particular is pre-eminent. Otter skins having coarse overhairs are greatly improved in appearance by plucking, as the fur is extremely soft and dense. When plucked, the fur is used either natural or dyed various shades of brown. A few skins are clipped. This fur is very durable, the leather being strong and fine-grained. In the natural state choice otter makes rich trimmings for seal sacques; and the plucked fur, both plain and dyed, is used for caps, gloves, capes, and garments. The skins are also used for coat collars and storm coats, more especially in Europe. In Scotland many are used in making the characteristic sporrans.

During recent years otter has been extensively dyed in imitation of the fashionable fur-seal, being cheaper than the latter, and when carefully and newly prepared can be distinguished only by experts. The price of good otter skins and the cost of dyeing the same is so great that these dyed skins have cost nearly as much as fur-seal. This has retarded their popularity, but with the advancing price of fur-seal dyed otter will doubtless find a larger market. In appearance it is the equal of seal skin and its wearing qualities are excellent. It is desirable to dye otter skins while in the raw state, as the grease prevents the dye from pentrating and injuring the leather, which would be weakened if the dye were applied after the skin had been dressed. Only the heavy-furred skins are selected for this purpose.

SEA-OTTER FURS.

The sea-otter yields the most valuable of all aquatic furs. The skins are of the greatest value in the third or fourth year of age, when the overhairs are scanty, exceedingly fine, and extend but little beyond the fur, which is usually dense, fine, and silky. There appears to be little difference in the quality of the pelage at different seasons of the year. The glossy, durable fur is about three-fourths of an inch in length all over the body, except that on the feet, head, and tail it is rather shorter, finer, and with fewer overhairs. The under portion of the back, the nose, and the upper lip are the only naked parts.

The color of the pelt varies considerably, the predominant shade being lustrous brown brightened with silvery overhairs. Some pelts are a deep brown or a brownish black, and are known in the trade as "black." Others are brown, with a tendency toward bluish green or dark-plum color, and are known as "dark." The fur is in all cases lighter on the abdomen than on the back. The hair on the head is lighter in color, and is light brown in the brown variety, but in the black animals it is almost completely white, the effect of the large number of white overhairs. The skins from British Columbia, Washington, and Oregon are frequently of a yellowish-brown hue, and albino skins have been taken rarely.

The choicest sea-otters have dense, brownish-black fur of silky, shimmering gloss and extreme fineness, exhibiting a silver color when blown open and with a reasonable number of white hairs regularly distributed, too many white hairs depreciating the value of the pelt. The skin of the male is usually more valuable than that of the female, being more brilliant and velvety in appearance. After they pass the age of perfection the fur becomes a dingy brown.

The skin is remarkably loose, like that on the neck of a young dog, and 12 inches or more of slack may be gathered in the hands from most parts of the body, the pelt of an individual 3 feet long readily stretching to 5 feet. A full-grown prime skin, which has been stretched before curing, is about 6 feet long and 24 to 30 inches wide.

The sea-otter belongs exclusively to the shores of the North Pacific Ocean and the adjacent seas, its range extending from Bering Sea southward to Japan on the Asiatic coast and possibly to Mexico on the American coast. It was formerly quite abundant throughout that region, but its numbers have been so reduced by excessive hunting that it is now very rare and in great danger of extermination.

The territory within which sea-otters are at present taken extends along the American coast from the Aleutian Islands southward to Washington, and on the Asiatic coast from Kamchatka to Japan. In most of that region, however, the catch is exceedingly limited, the annual product on the entire coast of the United States, exclusive of Alaska, for instance, not exceeding one dozen. The bulk of the catch is obtained now, as 100 years ago, among the islands of southeast Alaska.

The total product of sea-otter skins, obtained from the North Pacific since the development of the hunt, about two hundred years ago, approximates 700,000, made up as follows:

By whom obtained.	Number of skins.
Russian traders, previous to 1797.....	130,000
Russian American Co., 1798-1867.....	160,000
Miscellaneous traders, 1785-1828.....	250,000
Miscellaneous traders, 1829-1867.....	15,000
Miscellaneous traders, 1868-1900.....	145,000

Assuming that these skins cost the consumers an average of $150 each, we have a total of $105,000,000 expended for sea-otter furs, of which doubtless over 95 per cent came from residents of China and of Russia, and probably more than 80 per cent from the Chinese alone. A single skin has sold for $1,400, and though that is a fancy price, $700 or $800 is not unusual. The value is determined by the size, richness of color and texture, and the depth of the blackish hue studded with a suitable number of silvery hairs. The market value has varied somewhat from year to year, but has been high ever since the origin of the traffic in these furs. At the time of Cook's celebrated voyage to the North Pacific in 1778, the price of a prime skin was about $120 in China. In 1802, when the largest collection was made—25,000 skins—the average price of large and small at Canton was about $50 each. In 1840 prime skins sold readily for $150 each out of the vessel. The average price of all skins at the London sales in 1888 was £21, 10s.; in 1889, £33; and in 1891, £57; but the first-quality skins fetched much higher prices. At present, pelts average in value £65 each, including cubs as well as prime skins, while choice specimens readily fetch £200 each.

Seldom do the choicest sea-otter skins enter into the retail trade in America or England; and although the greater part of them are caught within the limits of the United States, it might be difficult at times to find a dozen skins in all the fur stores of the country. This fur has ever been held in high estimation by the Russians and Chinese, but the great cost limits its use to the wealthy classes exclusively. It is the royal fur of China, being worn by officers of state, mandarins, and other persons of importance in the Celestial Kingdom. In Russia it is used principally for the collars of overcoats. Sea-otter fur is also used for making muffs and for bordering fine garments made of textile fabrics or of other costly furs. Owing to its great weight as well as cost, entire wraps are rarely made of it.

While many sea-otter skins are marketed in Asia and Russia, probably 80 per cent of them pass through the London auction sales held in March of each year. The large decrease in the abundance of these animals is well illustrated by the decreasing numbers offered at those sales, the quantity sold at present being little more than 10 per cent of what it was twenty years ago.

The following shows the quantity offered at those sales during each of the last thirty years:

Year.	No. of skins.	Year.	No. of skins.
1871	3,824	1886	4,804
1872	4,307	1887	4,413
1873	5,095	1888	4,352
1874	4,920	1889	3,511
1875	4,564	1890	2,713
1876	5,059	1891	2,329
1877	5,420	1892	1,368
1878	5,258	1893	1,788
1879	5,176	1894	1,533
1880	5,583	1895	1,221
1881	5,647	1896	1,550
1882	5,657	1897	1,201
1883	5,680	1898	955
1884	5,038	1899	760
1885	4,908	1900	584

The sales of Messrs. C. M. Lampson & Co., London, for March, 1901, included 409 sea-otter skins,* of which 145 were large black skins, which sold at prices ranging from £52 to £280 each, or a total of £12,585 for the 145. The next largest class was a total of 118 large dark skins, varying in price from £48 to £125 each, or a total of £7,640. Only 14 brown skins were offered at that sale, of which 13 were large and one of medium size. Out of the total of 409 skins, there were 276 large ones, the others consisting of 96 medium, 25 small, 1 extra small, and 11 cubs. The average value of the large skins of all classes was £75 6s. 7d.; of the medium size, £50 8s. 10d.; of the small size, £35 6s. 5d.; of the extra small, £12; and of the cubs, £2 1s. 10d. Four very small cubs sold for 10 shillings each. While it is extremely gratifying that the large skins formed so high a percentage of the total number, yet it is to be regretted that there were any small skins whatever, and the taking of cubs was wanton destruction of valuable resources. The prices realized in 1901 were practically the same as in 1900, when 584 sea-otter skins were offered.

The following summary shows for each grade of skins at Messrs. C. M. Lampson & Co.'s March, 1901, sale, the number sold, minimum and maximum prices, total selling value, and average selling value:

Designation.	No. of skins.	Minimum price.	Maximum price.	Total value.	Average value.
Large, black	145	£52	£280	£12,585	£86.79
dark	118	48	125	7,640	64.75
brown	13	38	68	570	43.85
Medium, black	43	40	75	2,258	52.51
dark	52	32	70	2,549	49.02
brown	1	36	36	36	36.00
Small, black	11	32	42	393	35.73
dark	14	30	40	490	35.00
Extra small, dark	1	12	12	12	12.00
Cubs	11	½	3	23	2.09
Total	409			£26,556	£64.93

DRESSING SEA-OTTER SKINS.

The sea-otter should be skinned as soon as practicable after killing, and if caught far from the shore or from the vessel it should be laid out smoothly in the bottom of the boat and covered over with seaweed or otherwise protected. In skinning, a cross slit is made down the hind legs and a longitudinal cut made along the under side of the tail throughout its length, and the pelt drawn flesh side out over the body and head without cutting along the abdomen. No fur whatever is left on the carcass—tail, legs, and head being carefully stripped of their covering, though the fur on the legs and head is of relatively little value. The pelt, with the fur inside, is then tightly stretched on a stretching board. The fat adhering to the flesh side is carefully removed, the holes made by spears or otherwise carefully sewed up and the pelt placed in the open air, protected from the sun, to dry. When quite dry, the fur is combed and the pelt rolled up and stored in a safe place, where it is occasionally removed and examined for moths, etc.

The present method of dressing sea-otter pelts is much less complicated than the treatment of beaver or mink, but, owing to the great value of the fur, extreme care is taken at all stages. The flesh side is first dampened over night with salt water, and then greased with choice butter, and several skins at a time tramped in a foot tub for four or five hours. Fine hardwood sawdust is then added, and the tramping continued for two or three hours longer. On removal they are moistened with soap water over night and then shaved to thin the pelt, the same as in dressing beavers. Next they are worked in a tramping tub with fresh sawdust for two or three hours, and on removal are cleaned of sawdust, either in a beating drum or by striking with rattan sticks. After combing with a fine steel comb, the skins are ready for delivery. Owing to the care necessary in the process, the cost of dressing sea-otter skins is about $2 each, compared with fifty cents for those of beaver and otter. Unlike other cased pelts, sea-otters are rarely ever cut open at the fur dresser's.

* A total of 423 were offered, but only 409 were sold. This comprises the bulk of the sales of sea-otters throughout the world for that year.

GOLD AND SCIENCE.*

IF we peruse the table of the elements, as chemists, we shall certainly not select gold as of supreme interest chemically. Its position as chief among the noble metals, its patent of nobility, is based on its aloofness from common associations or attachments. Unlike the element nitrogen, it is mainly for itself and little if at all for its compounds, that gold is interesting. In it we can at our leisure study the *metal* rather than the *element*. Its color and transparence, its softness and its hardness, the density as well as the extreme tenuity of some of its forms—such were the qualities which recommended it to Faraday when he desired to study the action of material particles on light. I should like to repeat to you in his own words the reasons he gave for this choice: "Because of its comparative opacity among bodies, and yet possession of a real transparency; because of its development of color both in the reflected and transmitted rays; because of the state of tenuity and division which it permitted with the preservation of its integrity as a metallic body; because of its supposed simplicity of character; and because known phenomena appeared to indicate that a mere variation in the size of its particles gave rise to a variety of resultant colors. Besides, the waves of light are so large compared to the dimensions of the particles of gold which in various conditions can be subjected to a ray, that it seemed probable that the particles might come into effective relations to the much smaller vibrations of the other particles."

I may remind you that Faraday came to the conclusion that the variety in the colors presented by gold under various conditions is due to the size of its particles and their state of aggregation. Ruby glass or ruby solutions he proved are not true solutions, nor are they molecular diffusions of gold, but they contain the metal in aggregates sufficiently large to give a sensible reflection under an incident beam of light. Through the kindness of Sir Henry Roscoe I am able to exhibit to you some of the original ruby gold preparations obtained during this research, which were afterward presented to him by Faraday at the Royal Institution some years before his death.

By means of refined and ingenious optical methods Zsigmondy and Siedentopf have succeeded in making these ultra-microscopic particles visible in the microscope as diffraction disks; they have, further, counted the number of particles per unit area, and have from the intensity of their reflection calculated their size. In ruby glass the size of the particles in different specimens was found to vary from 4 to 791 millionths of a millimeter. No relation was found to hold between the color of the particles and their absolute size. This conclusion is in direct contradiction of Faraday's belief already referred to. Mr. J. Maxwell Garnett has recently shown that the color of metallic glasses and films is determined, not only by the absolute size of the metal particles, but also by the proportion of the total volume they occupy in the medium in which they are diffused. The results of Mr. Garnett's calculations are in close agreement with a number of the observations on the color and microstructure of thin metal films which I had already recorded, and they appear to me to supply the explanation of much that had appeared puzzling before. My own observations lead me to think that the actual microscopic particles which are to be seen, and the larger of which can also be measured, in films and solutions or suspensions, do not in any way represent the ultimate units of structure which are required by Mr. Garnett's theory, but

* From an address by G. T. Beilby delivered before the South African meeting of the British Association for the Advancement of Science.

that these particles are aggregates of smaller units built up in more or less open formation.

That a relatively opaque substance like gold may be so attenuated that when disseminated in open formation it becomes transparent is contrary to all our associations with the same operation when performed on transparent substances like glass or crystalline salts. The familiar experiment of crushing a transparent crystal into a perfectly opaque powder would not prepare us for the effect of minute subdivision on the transparence of metals. At first it might be supposed that this difference is due to the very rough and incomplete subdivision of the crystal by crushing; but this is not the case, for the perfectly transparent oxide of magnesium may be obtained in a state of attenuation comparable with that of the gold, by allowing the smoke from burning magnesium to deposit on a glass plate. The film of oxide obtained in this way is found to be built up of particles quite as minute as those of which the gold films are composed, yet the opacity of the oxide film is relatively much greater. The minute particles of the dielectric, magnesium oxide, scatter and dissipate the light waves by repeated reflection and refraction, while the similar particles of the metallic conductor, gold, act as electrical resonators which pass on some of the light waves while reflecting others. Specimens of films of gold and silver and of magnesium oxide are exhibited on the table and on the lantern screen. When the metallic particles are in this state of open formation and relative transparence, it was found that the electrical conductivity of the films had completely disappeared. Films of this description were found to have a resistance of more than 1,000,000 megohms as compared with only six ohms in the metallic reflecting condition.

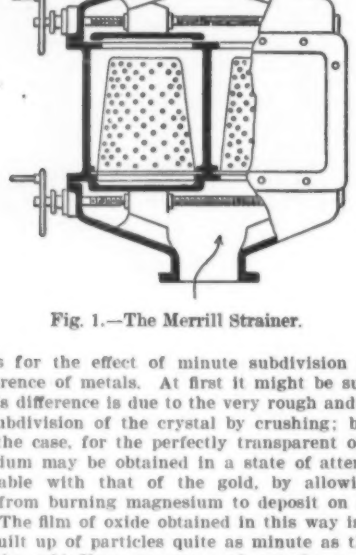


Fig. 1.—The Merrill Strainer.

MODERN TURBINE PUMPS.*

THE recent development of turbine pumps is due principally to the electric motor, which, on account of its high speed, is not well suited for operating reciprocating machinery. Although the rotary pump is not as efficient as the older kind, in combination with a motor it has so many advantages, such as compactness, simplicity and regularity of output and pressure, that its use is rapidly increasing. In the past this type of pump has been extensively used when it was necessary to raise large quantities of water a small distance—10 to 15 feet. The modern problem, to use it for greater heights by increasing its speed, has been solved by experience gained with turbines, which led to the use of diffusion vanes.

The chief peculiarity in the operation of the rotary as compared with the piston pump is that with decreasing speed the delivery is proportionately less only against a head diminished as the square root of the speed. This makes this pump particularly suitable for oil lines or other service where the only resistance is the friction in the pipe, which varies in the same proportion. In most cases an even speed is one of the conditions.

If, as is often the case, it is required to deliver an unvarying amount of liquid to a constant height, the rotary, or turbine pump, as it is called, when fitted with vanes, can be used. If, however, the amount to be delivered varies, two ways are open. One is an arrangement of several wheels in parallel which can be put in or out of service as required. This method is clumsy and unless the wheels that are not needed are motionless is uneconomical. The second and better way is to use a single pump, varying the delivery by changing the head by a throttle in the pressure line and designing the pump so that with a normal delivery the pressure is only slightly increased thereby. When the throttle is opened the amount delivered by the pump increases and *vice versa*. This of course affects the efficiency, but not seriously, as experience has shown, even when handling widely varying quantities of liquid. It is more difficult to insure an even flow with constant speed and varying height. This can only be done by arranging several wheels in series and cutting out those not required for the lower pressures.

THE EFFICIENCY OF TURBINE PUMPS

is, in the first place, dependent on the experience, skill and care of the designer, particularly in the choice of the angles of entry and delivery and the shape of impellers and vanes. Second, much depends upon the exactitude with which the design is carried out, as very small and seemingly unimportant variations affect the efficiency in a high degree. It is impossible to build efficient turbine pumps cheaply. The efficiency increases with the horse-power of the pump. With a 5-horse-power pump 60 per cent and with a 100-horse-power pump 80 per cent have already been reached, and it is very possible that with units of several hundred horse-power an efficiency of 85 per cent may be attained. These figures are based on the total height lifted, which in most cases has been increased somewhat by throttling and should be cut down from 2 to 5 per cent when making comparisons with piston pumps.

The correct measurement of the height to be lifted is an absolute necessity with pumps of this type, as an error in estimating the hydraulic resistance might easily make the whole plant useless. For instance, with constant speed the water might be lifted very close to the intended height without flowing, and also in course of time the efficiency will diminish because of leaks and wear and tear. The choice of speed is a matter of considerable importance. For example, a pump designed for 35 cubic feet a minute against a 328-foot head will give higher efficiency when constructed for 2,000 than for 1,000 revolutions per minute, as, in the first case, the water passages will be considerably shorter and the machine will offer less friction to the fluid. Finally, as might be expected, the efficiency increases with the number of stages in one housing. This is partly due to the relatively decreased friction in the stuffing boxes and partly, as experience has proved, to the fact that the impeller on the suction side is less efficient than those under pressure, so that the greater the number of the latter the less apparent will be the influence of the former.

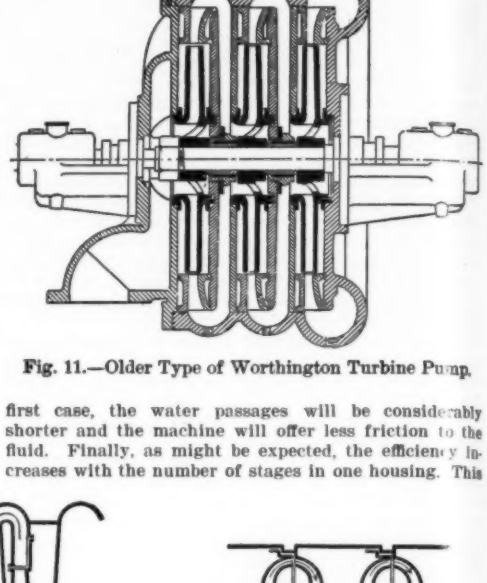


Fig. 11.—Older Type of Worthington Turbine Pump.

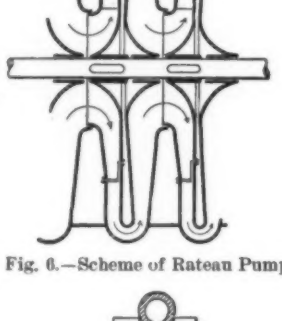


Fig. 6.—Scheme of Rateau Pump.

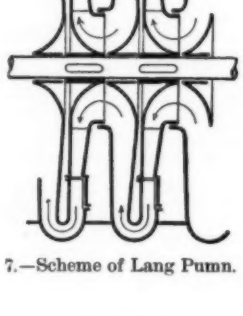


Fig. 7.—Scheme of Lang Pump.

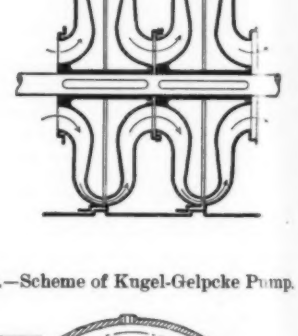
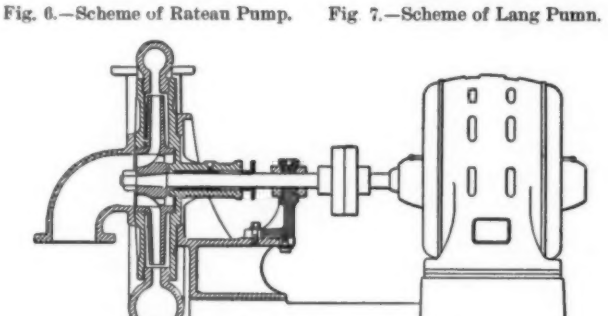


Fig. 8.—Scheme of Kugel-Gelpcke Pump.



Figs. 9 and 10.—Worthington Volute Pump.

Fig. 2.—Ordinary Centrifugal Pump of Older Type with Double Suction.

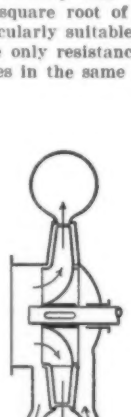


Fig. 3.—Centrifugal Pump with Single Suction.

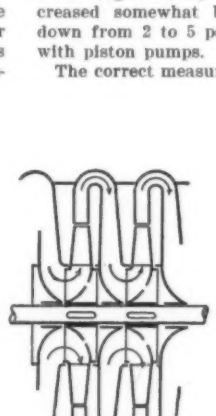


Fig. 4.—Scheme of Turbine Pumps of Worthington and Jaeger.

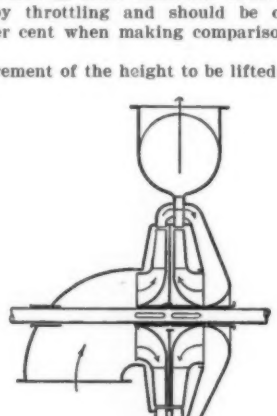


Fig. 5.—Scheme of High Pressure Centrifugal Pump of Sulzer.

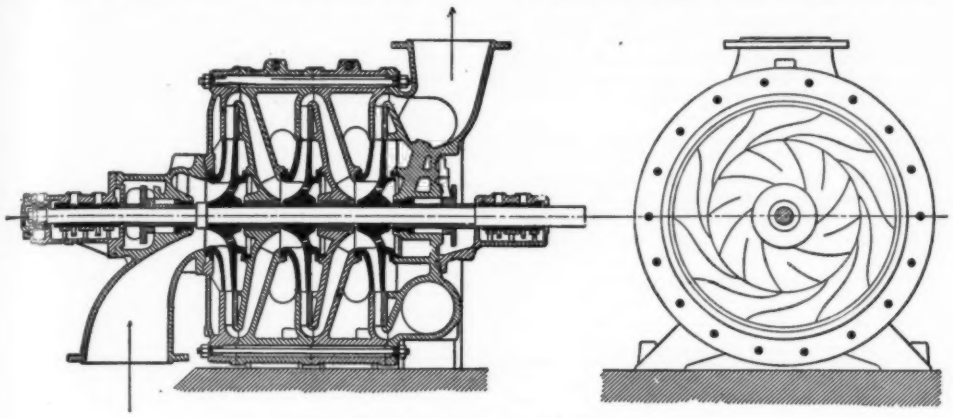
REQUIREMENTS IN THEIR DESIGN.

Practical points which demand consideration in building turbine pumps are in general the same as in other kinds. Particular stress must be laid on accessibility for removing foreign bodies, for cleaning and for replacing worn parts. An effort to construct any pump which will not be injured by foreign substances is useless, as the valves will necessarily suffer when anything comes between them and their seats. The most that can be done is to so design the parts that fracture will not occur and to subdivide the valves so that displacement of only a small part of them is probable. The correct and only sure way is to keep the foreign substance away, and the usual arrangement of one or more strainers has in practice proved very effective. Every such strainer under water will in time become choked and diminish the output of the pump. It is much better to place the strainer above the surface of the water instead of below it, as by stopping the pump it can then be removed and replaced by another very quickly. It is better still, but more complicated, to arrange two strainers in the suction line, either of which can be removed without stopping. A practical arrangement of this kind is Merrill's strainer, shown in Fig. 1.

The trouble with foreign substances is greater with turbines than with piston pumps, for with the sizes usually built, 8 to 10 inches diameter, with opening 0.3 to 0.4 inch wide, the chance of stoppage is greater than in ordinary pump valves. In the piston pump the foreign body has only to go through two valves, whereas in the turbine pump as many as twelve and even more impellers must be passed. In turbine pumps to clear

* Translation, by the Iron Age, of an article by Otto H. Mueller in Zeitschrift des Vereines Deutscher Ingenieure.

the end wheels of foreign substance the whole pump must be taken to pieces; therefore it is of great importance that the pump be easily taken apart and put together. Pumps in which impellers, vanes and other parts are in a closed housing, into which they are



Figs. 12 and 13.—Jaeger Turbine Pump.

pushed from one end, are at a disadvantage in this respect. The parts soon rust tight, making it difficult to get them out. The better construction is that in which the housing is divided into rings which are screwed together concentrically. Only single stage centrifugal pumps without vanes for handling large quantities of water against a low head are capable of passing foreign substances, and even they are liable to injury to the ends of the blades.

The trouble from sand in turbine pumps has been greatly exaggerated. It is just as harmful as in piston pumps attacking principally the interior packing and the stuffing boxes, which must be changed very frequently, but the impellers and vanes are seldom injured. This is because a well constructed pump is not liable to shocks, and where these do not occur sand in the water is incapable of doing damage. Hard water, such as is common in mines, forms a coating on the inner surface of the pump, which by diminishing the area lessens the efficiency.

TURBINE PUMP OPERATION.

The points to be observed in starting a pump and keeping it in operation are very simple. Above all, the pump should never run dry, as that leads in a very short time to heating up and destruction of the packings, and in some circumstances also to melting the bearings, bending the shaft and destroying the parting walls. Every pump must be provided with a funnel to fill it when starting, a foot valve in the suction line, air valves in each chamber and drain cocks to prevent injury by frost. In the pressure line there must be a non-return, or shut off valve, and preferably both. When starting the pressure valve must be closed and not opened until the pump has attained full speed and pressure. With direct current motors the pump can start with the valve partly opened. Safety valves are unnecessary, as with a constant speed a certain pressure cannot be exceeded. This renders starting the pump simple and safe and is one of its greatest practical advantages over piston pumps. When running all that is necessary is to insure constant lubrication of shaft bearings and stuffing boxes.

COMPARISON OF EXISTING PUMPS.

Modern turbine pumps are almost exclusively radial pumps without any great difference in the method of producing the speed. The chief differences are in the way by which end thrust is taken up. Figs. 2 to 8 show how this arises and how it is overcome. Fig. 2 shows the common centrifugal pump of the older type with double suction. As the whole construction is symmetrical end thrust cannot occur, but for multistage arrangement this form is practically useless. Fig. 3 shows a pump with suction on one side only, and on the other a chamber provided with packing rings and connected with the suction pipe. When both packings are of the same diameter the suction cannot cause end thrust, but a lateral pressure is formed by the diversion of the fluid. It is possible to balance the latter by making the packing rings of unequal diameter, but even then this form is unsuitable for building in series. The equalizing passage in Fig. 3 may be replaced by openings in the impeller between the shaft and the rear packing, and in the simplest manner possible the pump becomes suitable for arrangement in series. This is done in the Worthington and Jaeger turbine pumps (Fig. 4).

One sided impellers may also be used for multistage work if half of them are opposed in the direction of end thrust, the other half working in stages of equal pressure. The same result is attained if the wheels, keyed on right and left, are allowed to work together in pairs, as in Sulzer's high pressure pump, Fig. 5. Another method, shown in Fig. 6, is Rateau's arrangement, in which the impellers are all one-sided and all coupled in the same direction, but with the walls of each wheel made of unequal diameter, those toward the suction side being the greatest. Somewhat similar is Lang's construction, Fig. 7, in which the impeller blades end with the smaller diameter, so that the overhanging edge of the larger disk acts as the boundary of the diffusion vanes. In Fig. 8, which shows the arrangement of Kugel-Gelpcke's pump, the pressure of diversion which appears at the entry to each impeller is almost entirely counter-balanced by back pressure from the delivery pipe, and the pressure of the water in the passages on both sides of each wheel is counterbalanced by the increase in area.

The counterbalancing, shown in Figs. 6 to 8, by different areas, is not to be seen at a glance, as the varying diameters cause pressures, the variation of which cannot be judged offhand. However carefully the designer may have provided against end thrust some will

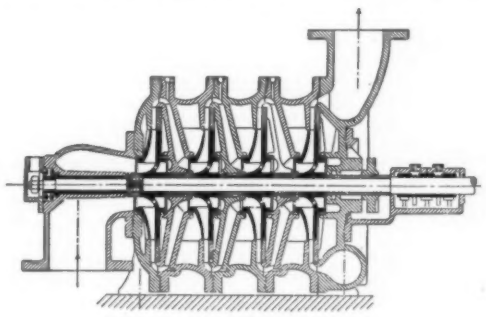


Fig. 14.—Jaeger Turbine Pump.

occur in operation, because the internal packings can neither be made nor kept absolutely tight. For instance, in Fig. 4, if one packing ring leaks more than another extra pressure results in the chamber between the latter and the delivery, and however slight it may be the large surface upon which it acts makes it important. As it is impossible to foresee which packings will become leaky, a certain end thrust, the amount and direction of which cannot be foretold, will occur and it can best be provided against by suitable bearings.

Figs. 9 and 10 show the so-called volute pump of H. R. Worthington, an ordinary centrifugal pump, which instead of vanes has a passage between the discharge slots in the impeller and the spiral pressure pipe. This passage assists so materially in transforming speed into pressure that these pumps, which are only made single acting and for lifts up to about 50 feet, have an efficiency of 70 per cent. The rotary member was at first provided externally with radial ribs intended to keep the liquid on each side in motion, thus lessening the difference in pressure at the packing and consequent leaks. This object was attained, but at the cost of such greatly increased friction that the ribs were removed. Fig. 11 shows a Worthington turbine pump of older construction which differs from more modern machines chiefly in the housing, this being cast in one piece, and in the crowded arrangement of the wheels. Figs. 12, 13 and 14 show turbine pumps built by C. H. Jaeger & Co. of Leipzig. The impellers and vanes are constructed of bronze and the shafts of nickel steel. For medium pressures the housing rings are bolted together by flanges, as shown in Fig. 14, while for higher pressures long bolts, as shown in Fig. 12, are used.

TESTS OF TURBINE PUMPS.

Figs. 15 to 18 show results of tests on turbine pumps. The abscissae represent the flow per minute, expressed in percentage of the pump's capacity. The upper curves show the lift obtained by throttling, the lower the efficiency when working against that lift. Fig. 15 represents experiments on a pump of 1,000 liters (264 gallons) a minute capacity against a head of 80 meters (262 feet) at 15,000 revolutions per minute. The maximum efficiency, 77 per cent, was obtained when pumping the rated capacity. Fig. 17 was obtained from a two-stage pump in Berlin, the rated capacity being 3,500 liters (925 gallons) per minute against 140 to 145 feet head at 870 to 890 revolutions per minute. In this case also the highest efficiency obtained was when running at the rated capacity, and amounted to 78 per cent. Fig. 16 is from a six-stage pump of 2,000 liters (528 gallons) capacity against 360 feet head at 1,470 revolutions per minute. The highest efficiency, 79 per cent, was obtained with a delivery of 1,700 liters (450 gallons) per minute and was only 77 per cent at the rated capacity. Fig. 18 shows the results obtained with a comparatively small four-stage pump intended for 420 liters (110 gallons) per minute against 207 feet head at 1,430 revolutions per minute. The highest efficiency, 73 per cent, was in this case reached at 360 liters (95 gallons), and with any output between 280 and 440 liters the efficiency was over 70 per cent. In this figure a curve showing the amount of power used is also drawn, which indicates that with closed

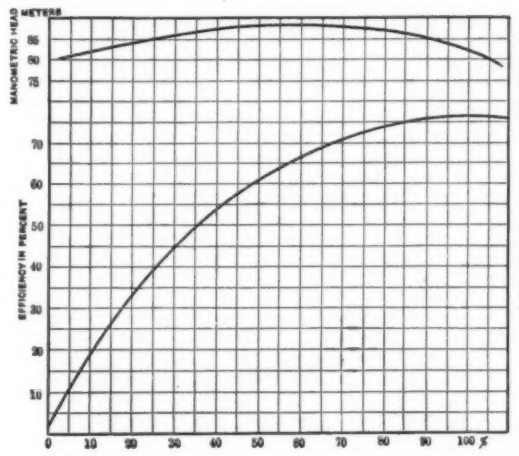


Fig. 15.—Results of Tests of a Four-Stage Pump, 1,000 Liters per Minute, 80 Meters Head.

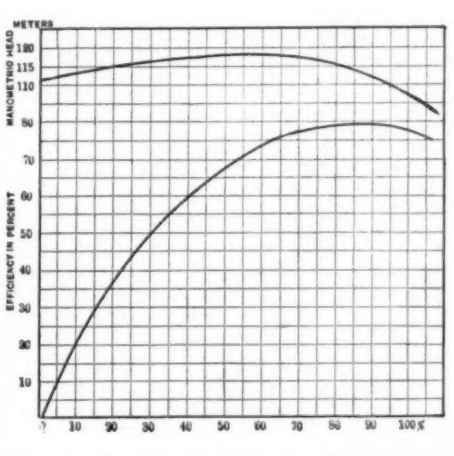


Fig. 16.—Results of Tests of a Six-Stage Pump, 2,000 Liters per Minute, 110 Meters Head.

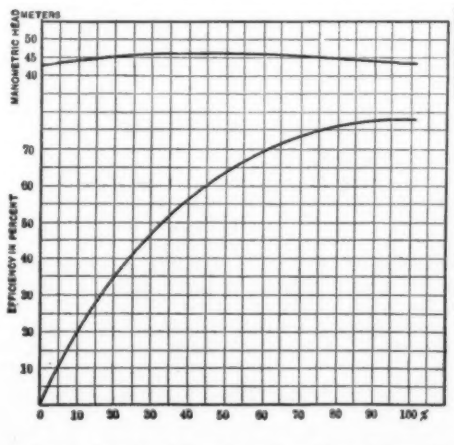


Fig. 17.—Results of Tests of a Two-Stage Pump, 3,500 Liters per Minute, 43 to 45 Meters Head.

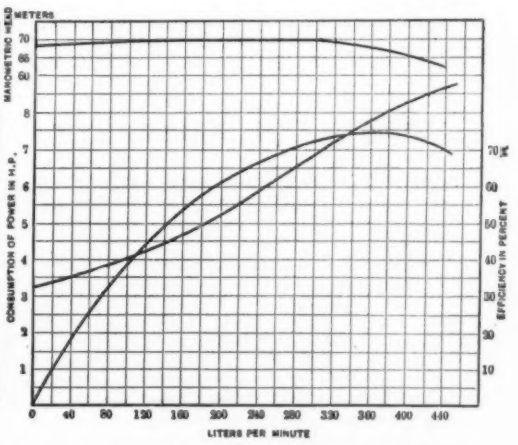


Fig. 18.—Results of Tests of a Four-Stage Pump, 420 Liters per Minute, 63 Meters Head.

throttle—that is, with no flow—the power required was 40 per cent of that at the rated delivery. This value is generally between 30 and 40 per cent, which is not unfavorable when only quite short intermissions are in question. In all the tests the pump, having been

primed, was brought up to full speed with closed throttle; the latter was then opened until the rated flow was reached. The overload was then given, upon which the throttle was gradually completely closed and finally opened again to yield the rated flow. The attainment of this point the second time invariably showed a higher efficiency, as in the elapsed 15 or 20 minutes the packings had worn smoother. The most striking feature about these tests is the comparatively flat course of the pressure curve and the easy course of the efficiency lines in the neighborhood of the normal capacity. This is attained by suitable form of blades.

THE UTILITY OF THE TURBINE PUMP.

Although the advantages of pumps of this class have, as is usual with novelties, been greatly exaggerated, there is no doubt that an extensive field is open to them, particularly where electric transmission can be used to full advantage. Owing to the many defects of direct acting pumps the turbine pump will probably be used for hydraulic purposes, for which their even pressure and their characteristic of stopping as soon as a certain maximum pressure is reached, with simultaneous decrease in consumption of power, make them particularly well suited. Practically any pressure can be obtained. Thus with 20 stages, which could readily be accommodated in two housings, at a speed of 3,000 revolutions per minute, 3,000 pounds per square inch could be obtained were such a pressure needed. As a matter of fact, Worthington turbine pumps have been used for operating hydraulic elevators in many of our large cities. On the other hand, where the use of steam cannot be avoided efficiency and adaptability speak for the piston pump.

At first sight the combination of the steam turbine and the turbine pump seems eminently appropriate. De Laval coupled a turbine pump directly to the shaft of his turbine, which ran at 20,000 revolutions per minute, whereby the wheel diameter was considerably smaller than that required for suction and discharge pipes, and Rateau attached a single acting pump of 0.315 inch wheel diameter to his turbine with a speed of 9,000 to 18,000 revolutions per minute. The delivery amounted to 400 to 420 liters per minute against 230 to 980 feet head, and the machine of course had to receive its water under pressure. In general it will be found that the speed of the steam turbine is such that it must either receive water under pressure or be divided into units working in parallel. The former case seldom occurs and the latter is not economical. Moreover, at its present stage of development the steam turbine in such small units as required for pumping purposes has not high enough efficiency to compensate in the least for the decreased efficiency of turbine pumps as against piston pumps.

For internal combustion engines a combination with the turbine pump would be still more rarely advisable than with the piston pump. It has the advantage, however, of requiring but little power to start and easy change of amount delivered without change of speed. As against these is the low efficiency, for which reason the decision will depend principally on the conditions in each case.

[Concluded from SUPPLEMENT No. 1558, page 24971.]

ON THE PERCEPTION OF THE FORCE OF GRAVITY BY PLANTS.*

By FRANCIS DARWIN, F.R.S.

EXPERIMENTAL EVIDENCE.

A FLAW runs through a great part of the experimental evidence, which may be illustrated by an experience of my own. I found[23] that seedlings of Setaria and Sorghum could be nearly deprived of statoplasts by means of a high temperature, and, further, that such destarched plants were markedly less geotropic than normal specimens. Here seemed a proof of the theory; unfortunately, however, it turned out that the plants in question were also rendered less heliotropic. These facts make it impossible to allow Nemec's gypsum experiment to be convincing. He caused a loss of starch by inclosing roots in plaster of Paris, and found that they had in great part lost their geotropic power. But he did not discover whether this loss depended on disappearance of part of the sense-organ or on general loss of curving power, though he has since (02) made the interesting observation that roots so treated are capable of hydrotropism. Again, Nemec found in resting seeds of *Vicia Faba* that the statoliths are undeveloped, and that they appear synchronously with the power of geotroping. Would not a similar thing be true of the apheliotropism of Sinapis roots—i. e., might it not be found that they were not heliotropic until the starch appeared?

The same objection must be brought against Haberlandt's otherwise convincing observation[24] that Linum growing out of doors in late autumn or winter is both devoid of statoplasts and incapable of geotropism, and that the power of curvature returns on bringing the plants indoors, when the starch reappears. The full value of these experiments cannot be made clear without going into more detail than is here admissible. They are particularly interesting because, as Haberlandt remarks, so far as they prove the truth of the statolith theory, they also disprove the pressure theory. This may also be said of other experiments mentioned in the present section.

We must, I think, object on similar grounds to Nemec's observations, suggestive though they are, on the absence of geotropism in certain individual leaves and roots which, through unknown causes, had no statoliths.[27]

The same must be said of the above-mentioned experiments of Haberlandt, in which geotropism is increased by rapid shaking in a vertical plane. I attempted[28] to avoid this fault in the similar experiments with a tuning-fork made independently, which showed that the effect of vibration in increasing reaction is far greater in the case of geotropism than in heliotropism.

Haberlandt (00) made the interesting observation that plants deprived of their endodermis by means of an operation lose the capacity of geotropism. Here, again, we ought to know how the operation affects sensitiveness other than geotropic; and, as Haberlandt grants, it may perhaps be said that the operation

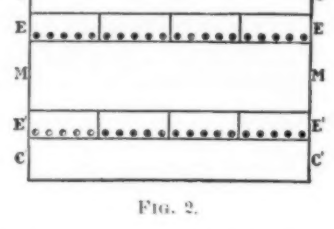


FIG. 2.

is too serious to allow of the foundation on it of a very convincing argument.

The question how far the statolith theory is applicable to the root is a difficult one. It involves the old and apparently insoluble difficulty of distinguishing between the removal of the tip of the root, considered as a perceptive organ, and the effect of the shock of the operation. The question is, moreover, complicated by contradictory evidence. According to Czapek, cutting off a small part of the root-tip, an operation which does not remove the whole of the statoliths, interferes with geotropism in the same way as does actual amputation.[29]

Nemec, on the other hand, finds evidence for the operation depending on the removal of the sense-organ; for according to him the power of geotroping does not return with the appearance of *general* symptoms of recovery, such as cell division and the growth of a callus, but only with the actual reappearance of statocytes.

Nemec's most recent experiments[30] are confirmatory of this result. He finds that Lupin roots, from which ½ millimeter, 1 millimeter, and 1½ millimeters respectively are cut off, behave differently. The ½ millimeter lot were clearly geotropic in seven hours, while no curvature occurred in the others. After a further interval of thirteen hours the 1 millimeter lot had curved. Microscopic examination showed that statoplasts had appeared in these roots, but not in the 1½ millimeter lot, which showed no geotropism. It is particularly interesting that according to Nemec the statoplasts appeared in a new growth which was visible as a slight convexity of the cut surface.[31]

An experiment by Nemec with the roots of *V. Faba* must also be mentioned. One millimeter was cut from the tips of each of a number of roots, and they were all placed horizontally. They were examined after fifteen hours, when considerable variety in the result of the operation was evident; some of the roots had bent geotropically, while others were still horizontal. On cutting sections it was found that the geotropic roots had statoplasts, the horizontal ones none. It may of course be said that the result depends on the effect of shock lasting longer in some individual roots, since, as Czapek has well said, the only proof of the

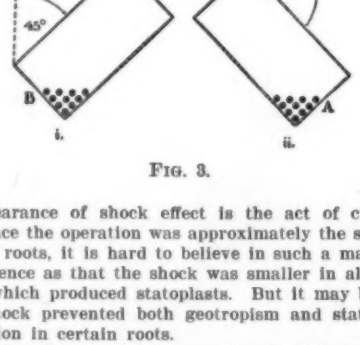


FIG. 3.

disappearance of shock effect is the act of curving. But since the operation was approximately the same in all the roots, it is hard to believe in such a malicious coincidence as that the shock was smaller in all those roots which produced statoplasts. But it may be said that shock prevented both geotropism and statoplast-formation in certain roots.

Czapek (02) quotes the experiment of Brunchorst, who found that a circular cut round the tip, not deep enough to free the terminal part, has the same effect as amputation. On the other hand, Nemec[32] states that geotropism persists, if the root-tip is cut half through by two opposite incisions in different planes, so that the whole of the tissues are divided, and yet the tip is not amputated. Thus four out of five bean-roots treated in this way showed distinct geotropism in 5¼ hours. This seems to me a striking result, as showing that the shock of the operation is not exclusively the decisive element. Nemec has, moreover, shown that if geotropic curvature has begun on a normal root, a wound interferes with the amount of after-effect, and that the precise nature of the wound is not decisive, and this, as far as it goes, confirms the assumption that two half-cuts would produce as much shock as amputation.

Czapek[33] finds that splitting a bean-root longitudinally has the same effect as decapitation. This would mean that decapitation produces its results by shock only, since in a split root there is no removal of the tip. I think I was the first to make use of the splitting of roots in this connection. I wished to show[34] the incorrectness of Wiesner's view—viz., that amputation prevents geotropism by checking growth. In my experiments the split roots were greatly checked in growth, but curved geotropically, behaving in this respect quite differently from amputated specimens.

Another striking bit of evidence on Czapek's side of the question[35] is the fact that Lupin roots from which "½ millimeter of the tip has been removed, and which, therefore, contain no statoliths," show the remarkable homogentisin reaction which he has convincingly proved to be a symptom of gravi-perception. Czapek adds that the same is true of roots from which 1 millimeter has been removed. It seems to me that Nemec's reply to this[36] is of value. He finds that the root-cap in Lupin is variable in length, but always longer than ½ millimeter; therefore, in the roots from which ½ millimeter only was removed there should have been some statocyte tissue remaining. Even after the removal of 1 millimeter the root can, according to Nemec, rapidly form statocytes, since the section is in the neighborhood of the calyptrogen.[37]

Nemec suggests it to be conceivable that differences of pressure in Czapek's sense may give rise to the homogentisin reaction, while the true act of graviperception is confined to the statoplasts. This is no doubt possible, but I confess that, if the homogentisin reaction can occur in root-tips which have no statoliths I should consider it a strong argument in favor of the view that pressure-difference in Czapek's sense supplies the machinery of perception in roots. Czapek also claims that his experiments with bent-glass tubes (Czapek, 95) prove the gravi-perceptive region of the root not to be confined to the region of statoplasts, since if the root-cap alone is in the vertical branch of the tube, geotropic curvature is not excluded. Nemec (04) has attempted a rejoinder to this objection: with what success readers must judge for themselves.

It will be seen that, in my opinion, the balance of evidence is not fatal to the statolith theory. Czapek, who treats the question in a broad and liberal spirit, is by no means inclined to deny that statoliths have a share in graviperception; all he claims to prove is that the statoplasts do not supply the whole of the mechanism. It is not easy for an upholder of the theory to allow this much in the present stage of the controversy. The best way of testing the theory is by comparing the distribution of geotropism with that of statoliths; and if we are to allow, in all cases which are opposed to the statolith theory, that the stimulus depends on pressure differences in Czapek's sense, we deprive ourselves of the best means of proving the truth or falsehood of our theory. Those who uphold the theory must have the courage of their opinions and finally trust to the facts of distribution. But further knowledge is necessary before such a judgment can fairly be made.

CENTRIFUGAL FORCE.

Jost[38] objects that plants on a centrifugal machine do not behave as the theory would lead us to expect. Thus he found that certain roots and seedlings showed geotropic curvature, although the statoplasts were scattered through the cell, not spread out on the cell-walls furthest from the axis of rotation. Miss Pertz[39] and I have repeated some of Jost's experiments, and have come to an opposite conclusion. We find that Setaria does not curve with a centrifugal force of less than 0.2 *g.*, and this is about the limit for visible displacement of the starch-grains. As the centrifugal force increases up to 0.04 *g.* we get slight amounts of curvature and slight amounts of starch displacement. The two phenomena cannot be accurately compared, but so much is clear: that the result of Knight's experiment is not destructive of the statolith theory, but, on the contrary, is roughly in harmony with it.

The result of an intermittent stimulus may seem to some a difficulty. Jost[40] produced geotropic curvature by placing seedlings in the horizontal and vertical positions for alternate periods of 3½ minutes. With alternate periods of 50 seconds horizontal and 2 minutes 30 seconds vertical, he sometimes failed

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* Read before the British Association for the Advancement of Science.

[23] F. Darwin (03).

[24] Haberlandt (03). It seems, however, that the starchless plants had some heliotropic capacity.

[27] Nemec (01).

[28] F. Darwin (03).

[29] Czapek (02, p. 118).

[30] Nemec (04, pp. 46, 53).

[31] This agrees, as Nemec says, with Wachtel's (99) result, who found geotropism returning before the whole tip was regenerated.

[32] Nemec (01, p. 19).

[33] Czapek (98, p. 202) and (02, p. 118).

[34] F. Darwin (82).

[35] Czapek (02, p. 468).

[36] Nemec (04, p. 53).

[37] He adds that the calyptrogen may in this way have an indirect importance, and Firtsch's belief that this tissue was the essential seat of graviperception may be accounted for.

[38] Jost (02).

[39] Darwin and Pertz (04). By an oversight we omitted to give a reference to Nemec's (02, p. 347) interesting reply to Jost's criticism.

[40] Jost (02), p. 175. See also Czapek (98), p. 206; and Noll (00), p. 462.

to get a geotropic curve, and exposures if less than 50 seconds always failed. It is commonly said that 15 to 25 minutes are needed for the starch to fall onto horizontal cell walls, and it may seem, therefore, that in these experiments neither 3½ minutes nor, *a fortiori*, 50 seconds could produce a change of position in the statoliths, and that therefore the experiment is destructive to the theory. But this would be a wrong conclusion, for, according to my experience, the falling time of starch is often less than 15 minutes; and even if this were not so there would be no difficulty in understanding the above experiments for, as Jost allows (*loc. cit.*), and as Nemec (02) has also pointed out, the statoplasts may stimulate the cell without the occurrence of any visible displacement; for if the statoplasts do not fall over and spread out on the horizontal walls there must be a column or heap of starch-grains, the height of which equals the width of the cell, resting on the lateral wall of the cell instead of, as in the normal position, a shallower layer pressing on the basal wall. Here we have plain conditions of differentiation between the vertical and horizontal positions.

The same considerations apply to the whole question of what is known as the geotropic presentation time[42]—i. e., the minimal period of horizontality needed to induce a geotropic curvature. It has been said that the presentation time corresponds with the time needed for the statoliths to fall on to the horizontal walls of the sensitive cells. It seems to me that we hardly have knowledge enough to be certain of this coincidence and since, as above pointed out, the statoliths may begin to stimulate before they are visibly displaced the question is not one of much interest or deserving of special inquiry.

THEORETICAL.

Elfving's[43] well-known experiment with grass haulms shows that (in this instance) the action of the klinostat depends, not on the prevention of all gravireception, but on the equal distribution of stimulus.[44] But other plants react differently—that is to say, they do not exhibit increased rectilinear growth on the klinostat. This can best be accounted for, as Noll[45] suggests, by the supposition that the equally distributed stimulus tends to produce a simultaneous increase and decrease of growth-rate on opposite sides of the rotating plant.[46] We, therefore, get in an indirect way evidence in favor of what has not been directly proved—namely, that in geotropic curvature the diminution of growth on the concave side is not the result of compression produced by the increased growth on the convex side, but rather an independent reaction. It is necessary, therefore, to inquire what theoretical conclusions may be fairly made as to the stimulation correlated with such a mechanism of curvature. Noll[47] uses the term "Reizfeld," or "stimulation-area," to express the regions in which graviperception occurs. The distribution of these areas is expressed in diagrams which serve as shorthand methods of recording the geotropic reactions of various organs. All such ways of clarifying and expressing our ideas of the laws of perception are useful. I must confess that I do not find Noll's terminology easy to use, and I prefer to express the same ideas in terms of the distribution of the pressure of statoliths on the different parts of the ectoplasm of the gravi-sensitive cells.

Imagine an apogeotropic shoot placed in the horizontal position as shown in longitudinal radial section in Fig. 2, where *C* and *C'* are the cortical tissues and the seat of motile power; *E* and *E'* the endodermis, the supposed region of graviperception; *M*, the central tissues, which do not concern us.

The fact that the statoliths now rest on the horizontal (tangential) walls differentiates the horizontal from the vertical position of stable equilibrium. But what circumstance is there that can be conceived to originate curvature in one direction more than another? It can only be that in the endodermis *E* on the physically upper side the statoliths rest on the outer wall. This view agrees with Noll's hypothesis of the arrangement of stimulation-areas. There is no difficulty in believing that the inner and outer tangential walls have different individualities: Vöchting's work[48] on transplantation seems to indicate that this is the case. And if this analogy with formative polarity is not allowable, we must still insist that the presumption is in favor of *E* and *E'* in Fig. 2 being in different conditions, since we have certainly no right to assume that the outer and inner walls are identical in what we have called their individuality.

It is not here necessary to go into the question whether the radial walls of the endodermis are or are not sensitive since the problem of geotropism in its broad outlines is not concerned with it.[49]

THE POSITION OF MAXIMUM STIMULATION.

This problem involves the question whether an orthotropic organ in the vertical position is or is not freed from stimulus. We will first take the question as to the existence of a stimulus in the normal (i. e., not the inverted) position. One of Pfeffer's[50] arguments for the existence of a stimulus is as follows. A root having been allowed to curve from the horizontal to the vertical position is placed on a klinostat, and after a time the curve disappears. It is therefore assumed that there existed a geotropic stimulus keeping the root curved until the stimulus in question was rendered inoperative by the klinostat, when the rectipetality of the root could have free play. But it is not a necessary conclusion that while the root is strictly vertical any stimulus is acting. If from some internal cause the root leaves the vertical, the ordinary geotropic curvature depending on the stimulation of the tangential walls will come into action and bring the root back to the vertical. To translate into the language of the statolith theory, it is not necessary to assume that the lower walls of the graviperceptive cells are sensitive to the pressure of the statoliths—the sensitiveness of the tangential walls will suffice. The experiment above mentioned does not therefore seem to prove that an orthotropic organ in stable equilibrium is stimulated. But it is quite conceivable that a stimulus might be originated by the *loss* of pressure on the lower wall, for this would be a well-marked change in the internal condition of the cell, and therefore might become associated with a reflex. Thus, when an organ is placed horizontal the stimulus from the pressure of statoliths on the lateral walls (now horizontal) may be combined with, or in some way influenced by, the loss of pressure on the terminal wall of the cell which was formerly horizontal. But if the absence of pressure on a cell-wall acts in this way are we not bound to consider the pressure (when present) as a stimulus? I think we are, and therefore, though I do not think that the particular experiment referred to supplies the necessary evidence, I hold the lower wall of an orthotropic cell to be sensitive to the stimulus of statoliths, though such stimulus cannot be of a *directive* nature.

Since an organ when accurately inverted[50] and prevented from circumnutating receives no impulse to curve, it is assumed that the normally upper cell-wall (which is now below) is not stimulated. According to the statolith theory it is inconceivable that the organ should curve, since uniform pressure on the horizontal terminal wall cannot determine the *direction* in which such curve shall begin.

But though no directive stimulus seems to be a possible result of uniform pressure on the end-walls, it does not follow that such pressure has no effect. It seems to me that such a striking change as pressure on a wall which in normal circumstances does not receive pressure may very well modify the result of the normal stimulation of the lateral walls of the cell.

Czapek[51] has shown that with both stems and roots the gravistimulus is greater when the organ is removed from the normal vertical position by 135 deg. than when it deviates from the normal by 45 deg. In the case of an apogeotropic shoot the position of the starch in the endoderm is given in Fig. 3. The pressure of the starch on the lateral walls is the same in the two cases. In i., however, the starch rests partly on the basal wall (*B*), while in ii. it rests, to the same degree, on the apical wall (*A*). On the usual assumption that the basal and apical walls are insensitive, there is nothing to differentiate i. from ii. I cannot help suspecting that the pressure on the apical wall does in some way affect the sensitiveness of the tangential walls. If the pressure on the wall (*A*) was in itself the decisive element we should expect the stimulus to increase as the angle increased—from 135 deg. to nearly 180 deg.—which is not the case. From my point of view we can dimly understand why 135 deg. should be the position of maximum stimulation. It would be the result of a compromise, being a position in which the combined pressure on both lateral and apical walls was as high as possible[52]—a mean, in fact, between full pressure on the lateral walls (as in the horizontal position) and full pressure on the apical walls (as in the vertical position).

If some such theory is not adopted we must imagine with Haberlandt that the difference between positions i. and ii. depends on the weight of the statoliths in i. being on the *basal half* of the lateral wall, and on the apical half in ii. It seems to me that the difference of sensitiveness in the two regions would have to be very great, considering that in the horizontal position, in which the gravistimulus is less than in position ii., the full pressure of a considerable fraction of the total starch acts on the supposed extra-sensitive region of the cell-wall.

But when all has been said there remains a difficulty with which I do not know how to deal. It is clear that, according to either theory, the critical position should be the horizontal, and that as the organ is moved further and further from the normal (in successive experiments) the geotropic reaction ought to increase decidedly as the horizontal is passed; and this is not the case.

DIAGEOTROPISM.

The diagram, Fig. 2, will serve to represent a diageotropic organ in stable equilibrium. In spite of the fact that it is at rest in the horizontal position, we must assume that the tangential (horizontal) walls of the endodermis are sensitive to the pressure of the statoplasts. For when the organ is placed obliquely it has the power of returning, by curvature, to the horizontal; and this requires that the plant shall distinguish up from down. If its apex is above the horizon it must curve downward, i. e., toward that side on which the statoplasts rest on the *external* walls of the endoderm cells, and *vice versa* if the apex is below the horizon. But what signal tells the plant that it is not horizontal? This can only be effected by the statoplasts pressing on the basal or apical walls, as in Fig. ?.

The difficulty is increased by the fact that when a diageotropic organ is fixed vertically, the apex being up or down,[53] no curvature follows. This, according to the usual idea, would mean that the terminal walls are not sensitive. But the walls must be sensitive in some way, or the plant would not react to the gravistimulus, as it undoubtedly does. The only conclusion I can come to is that the position of the statoliths shown in Fig. 3, in which they rest partly on the terminal wall and partly on the lateral (tangential) wall, must be capable of giving the combined stimulus,[54] as above suggested.

Personally I do not attach great importance to the details of how the statoliths act on the different walls of the cells, although as part of the history of the inquiry I feel bound to discuss it. The broad fact that the statoliths rest on different parts of the cell-walls when the geotropic organ is placed at different angles with the vertical seems to me sufficient. The precise manner in which various reactions are associated with the position of the statoliths may be confessed to be for the present beyond our knowledge or powers of imagination, and such confession need not weaken the position of our theory.

Finally, I desire to say a word on a subject having but a remote connection with my theme. There is at the present time a tendency to pay an increasing attention to what is known as rectipetality or autotropism—viz., the inherent capacity of rectilinear growth. In my Cardiff Address[55] to Section D, I showed that rectipetality is really part of the phenomena of circumnutation. We must believe that rectipetality does not merely come into play in those comparatively crude experimental instances in which a geotropic curvature is flattened out by means of growth on the klinostat. We must believe that it also corrects curvatures which arise from the slight irregularity of normal everyday growth. This will imply that normal growth is built of a series of internal corrections; in other words, of circumnutation. The point I wish now to emphasize is that the stimuli, be they of geotropic or any other nature, should be conceived as acting not on a stationary, but on a moving plant—acting, in fact, on the spontaneous correcting power, whether we call it rectipetality, autotropism, or circumnutation. It is impossible to say how this consideration might modify our speculations as to the manner of action of the gravistimulus. It is quite conceivable that it might not alter our theoretic views at all, but without more knowledge we cannot be certain. My only point at present is that if we are led into contradictions or confusion by attempts to analyze what goes on in the gravisensitive region according to the statolith theory, such a result must not be held to be fatal to the theory until we know more of the problem.

In conclusion—and to clear our minds of the doubtful speculations in which I have entangled myself—I should like to reiterate my belief in the general, though not the universal, applicability of the Statolith theory. I find it impossible to doubt that, in the case of the higher plants, sensitiveness to the pressure of heavy bodies will be found to be by far the most important, if not the exclusive, means by which gravity is perceived. We have seen that the stimulus must depend on weight; and since neither the theory of radial pressure nor Noll's supposition of stimulation by small unknown bodies lends itself to experimental inquiry we are driven, as practical people, to test the views of Haberlandt and Nemec.

I base my belief partly on what I have already said, namely, that geotropism, being an adaptive reflex action, must during its development have been correlated, by that mysterious bond which unites stimulus to reaction, with some change, by which in the natural course of events it is uniformly preceded. Now the most obvious change which precedes geotropism is the disturbance of the falling starch-grains. This fact, together with what we know of the distribution of statoplasts, would almost force conviction on me. But this is not the whole of the evidence. We know from Nemec's researches that the protoplasm, in the cells assumed to be sense-organs, is sensitive to the pressure of the statoplasts; and we know from zoological evidence that heavy bodies resting on a sensitive surface can function as a sense-organ for gravitation. Finally, the experimental evidence, though not absolutely convincing, has not revealed any absolute bar to our belief in the statolith theory, and has brought to light a number of facts harmonizing with it in a remarkable manner. It seems to me that the theory of Nemec and Haberlandt may fairly hold the field until a better theory of graviperception and a better theory of the function of falling starch-grains are established.

[42] Czapek (98), p. 183.

[43] Elfving (84) proved that the pulvini of grass haulms increase in length when kept in slow rotation on a klinostat.

[44] My experiments on the germination of Cucurbita demonstrate the same point (Darwin and Acton, 94). Czapek (02, p. 369) shows that the homogentisin reaction occurs on the klinostat.

[45] Noll (92, p. 35).

[46] We have shown (Darwin and Pertz, 04) that in *Setaria* the statoliths undergo changes of position on the klinostat, indicating a succession of stimuli. See Heine (85), who briefly describes similar changes.

[47] Noll (92, p. 19).

[48] Vöchting (92, p. 151).

[49] See the discussion in Haberlandt (03, p. 467).

[50] Pfeffer (93, p. 19). I am only concerned with this special point, not with Pfeffer's general argument.

[50] In the whole of this discussion the organs are supposed to be supported by the morphological base.

[51] Czapek (95, 1). As doubt has been expressed as to the actual facts, it is worth while mentioning that Miss Pertz (99) has confirmed his results for the haulms of grasses.

[52] The fact that at angles above 135 deg. the stimulus remains greater than when the organ is horizontal seems to point to the conclusion that the share of the end wall in graviperception is relatively great.

[53] Czapek (98, p. 243). Noll (92, p. 37) had foreseen on theoretical grounds that this would prove to be the case. See also Noll (00, p. 473).

[54] In Noll's diagram of the stimulation-areas in a diageotropic organ the obliquely placed areas seem to suggest a similarity to what is here given [see Noll (92, p. 29)]. But his stimulation areas in which only a single statolith occurs are not strictly comparable to cells containing numerous statoplasts.

[55] F. Darwin (91).

[Continued from SUPPLEMENT No. 1558, page 24966.]

IRON AND STEEL HULL STEAM VESSELS OF THE UNITED STATES.—V.*

By J. H. MORRISON, Author of "History of American Steam Navigation."

STEEL SHIPBUILDING IN UNITED STATES.

THE manufacture of steel in this country dates from a very early period, but it met with very indifferent success. It was used mainly for tools and agricultural implements. During the period of the civil war in this country, the Bessemer process of steel making was first introduced in the United States. An experimental plant was established in 1862 at Wyandotte, about ten miles below Detroit, Mich., on the Detroit River, by E. B. Ward, adjacent to his extensive Wyandotte Rolling Mills, subsequently called Eureka Iron Company, for the making of steel ingots to roll into rails. The process here used was one invented by William Kelly, of Eddyville, Ky. On account of the delays incident to all new departures in manufacturing, and other causes, the machinery was not completed for the operation of the works until September, 1864, when the first steel made in this country, under what was practically the Bessemer process, was produced. This mill made but a small amount of steel when it ceased operations, and as the experimental steel works under the Bessemer patent commenced operations but a few weeks later, they found it to their mutual interests to form a consolidation in 1866 as the Pneumatic Steel Association. The original Bessemer steel mill under the Bessemer patents in this country was started at Troy, N. Y., by Winslow, Griswold & Holly, and their first conversion of steel took place on February 16, 1865.

The open-hearth process in the making of steel under the Siemens-Martin patents was introduced in this country a few years later, and was attended, like the introduction of the Bessemer process, with its many discouragements and trials attending a new departure in any process of manufacturing. This process for making steel was first introduced in 1868 by Cooper, Hewitt & Co., of Trenton, N. J., and some time after a few other manufacturers adopted its use. The first plant that was built for the exclusive manufacturing of steel by this process in this country was the Otis Iron and Steel Company, of Cleveland, Ohio, in 1874.

The first vessel built in this country having steel plates in her construction was the propeller tugboat "Sport," of 65 x 14 x 9 feet 6 inches, in 1873 at the Wyandotte shipyard of E. B. Ward and Frank Kirby. The shapes in the vessel were of iron. The steel plating used in the vessel was rolled from some of the ingots left at the time of the closing down of the experimental steel plant at Wyandotte, as previously mentioned. David Bell, of Buffalo, N. Y., plated three small steam yachts he built in 1875 with steel plating rolled at a plate mill in Buffalo.

Steel plate of American manufacture was used at this period for several marine boilers. The first built was in 1870 by the People's Machine and Boiler Works, of Baltimore, Md., for the U. S. revenue steamer "Northerner." In 1873 the owners of the steamboat "Mary Powell," of New York, had two steam boilers constructed of steel for the vessel by Alex. Cauldwell, of Newburg, N. Y.; and the same year Murphy, McCurdy & Warden, of New York, built one boiler of steel for the steamboat "Shady Side" for New York waters. All of this steel was made by Park Brothers Co., of Pittsburg, Pa. The braces, tubes, and rivets were of iron.

The first marine boiler built in this country of steel was that for the steamer "William G. Hewes" of Morgan's line in 1860, by the Morgan Iron Works, of New York city, of English plate steel. The machinery of the vessel was built at the Morgan Iron Works, and the iron hull by the Harlan & Hollingsworth Company. It was a stern-wheel vessel, having dimensions of hull of 149 feet by 29 feet 9 inches by 4 feet, with two high-pressure engines, each having cylinders of 15 inches by 5 feet stroke. The angle iron used in the hull was made by Lewis, Oliver & Phillips, the channel iron by the Carnegie Steel Company, and the iron for bulkheads by Moorhead, McCleap & Co. The hull plating was of crucible homogeneous steel of 70,000 pounds tensile strength, made by Howe, Brown & Co., Pittsburg, Pa. The bow plates and the knuckle plates were 3/16 inch thick, and the balance 6 pounds to the square foot, single riveted with ¾-inch rivets. The hull was sent out in sections and re-erected at Barranquilla, and the vessel was completed ready for service under steam in February, 1879.

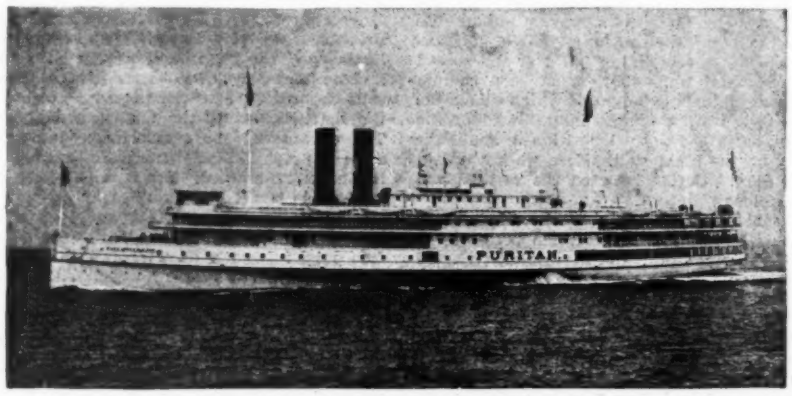
The "Victoria" was contracted for late in 1879 by the same company as the former vessel, and completed early in the next year. This vessel was 157 x 33 x 5 feet hold, being somewhat larger than the "Francisco Montoya," and with more power for propulsion. The angle iron was furnished by the Carnegie Steel Company. The hull plating was of the same kind of steel as used in the first vessel, and made by same steel company.

The Zulia River Navigation Company, of New York, contracted with the same builders in June, 1880, for a steel-hull stern-wheel steamboat named "Venezuela," to open navigation on the Zulia River in Venezuela. The hull was 120 x 24 x 3 feet deep. This was the first steam vessel built in the United States to have steel angles and floors, and of unequal legs, being 2, 2½, 3.7 pounds per foot. The rolls were made especially for this angle steel to secure the weight. This vessel may be said to be the first *all-steel* vessel built in this country. The angle steel was made by the Carnegie Steel Company. The steel of forward keel and bow plates was No. 8 gage, knuckle plates No. 7 gage, and balance of hull plating No. 10 gage; all of crucible homogeneous steel, made by Howe, Brown & Co. The six bulkheads were of No. 12 steel plate made by Moorhead, McClean & Co. There were steel transom and engine beams, with deck under engine beams of steel. During the same year the builders constructed for the Magdalena River, Republic of Colombia, the steamer "Roberta Calisto," and the "Irma" for service at Greytown, Nicaragua, both having steel plating like the former vessels. They were each 110 feet long. At the same time they built the "H. H. Benner" for the National Board of Health of the United States, having hull dimensions of 112 x 18 x 4 feet. The steel plate of the hull was made by the same manufacturers as that furnished for the previous named vessels. The bow and knuckle plates were 8½ pounds, bottom and sides 7½ pounds per foot; all double riveted. There were at the same time three steam launches built for the same board, each 37 feet long, and having steel plating of No. 16 gage.

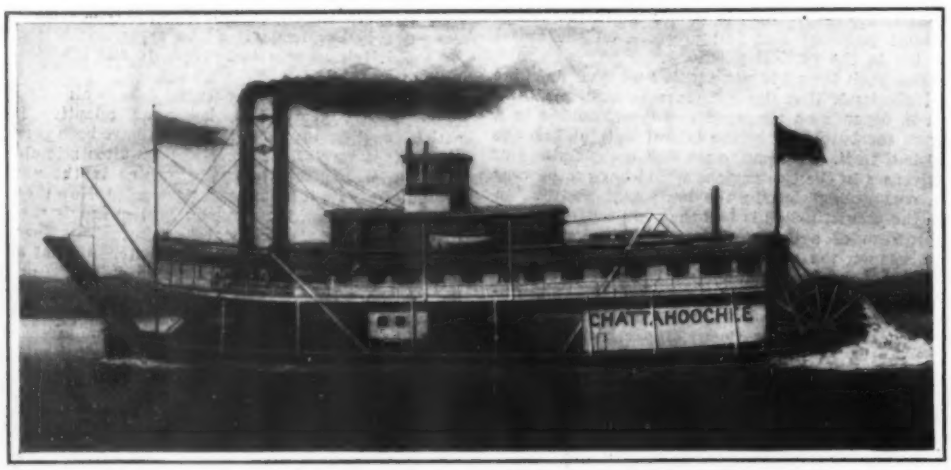
The steamer "Chattahoochee" was contracted for in June, 1881, for service on the Chattahoochee River in Georgia, and was the first *all-steel* steam vessel built in the United States for service in American waters. The length on deck was 155 feet, beam 31½ feet, depth of hold at knuckle 4 feet 6 inches, shear forward 30 inches, with 30 inches guards. Frames 2 x 2½ inches by 4 pounds spaced 18 inches centers; deck beams 2 x 3 inches by 5-pound angles, of steel, made by the Carnegie Steel Company. The steel plating of the hull was made by Howe, Brown & Co., of homogeneous crucible steel of 70,000 pounds tensile strength. The forward plates and the knuckle plates were of No. 6 gage, and the balance of the plating No. 9 gage, all double riveted. The bulkheads were also of steel plate. The motive power was two high-pressure engines, each having cylinders of 15 inches diameter and 5 feet stroke, and three boilers, each 20 feet long and 42 inches diameter. It was a stern-wheel steamboat, having a waterwheel of 18 feet diameter. This vessel was run on the Chattahoochee River, then taken to the St. Johns River in Florida, and run there for several years, and subsequently was in service from Vicksburg on the Mississippi River to Greenville, Miss. She was destroyed by fire while lying up at Vicksburg for repairs on December 6, 1893. Estimated value of vessel at time of destruction, $40,000.

The Pusey & Jones Company, of Wilmington, Del., built for the Magdalena River in South America, late in 1879, two steam vessels about 130 feet long, having steel hull plating rolled by Hussey, Brown & Co., of Pittsburg, Pa. They also built a stern-wheel steamboat 120 feet long in 1881, and in 1883 another of the same type of 150 feet in length, both for South American waters, and having steel plating. In all, they constructed ten vessels in four years, both steam and sail, that were constructed partly of steel. If not in error, one or two of these vessels had imported steel plate used in their construction.

The manufacture of steel plate for shipbuilding purposes was still in its experimental stage for some years after the building of the "Sport" in 1873. It was at the time Congress was taking some action toward the improvement in our naval vessels, during their searching inquiries into the questions of the best means and material to be used in the construction of the proposed vessels, that the doubt of the advisability of using steel in the construction of the vessels came before them, both from those in private professional life, as well as those in the naval service. There was a marked difference of opinion on the subject among the members composing the first Advisory Board of the Navy, and that may have had some influence, through Congressional action, in having a second board appointed. There is no doubt but at this time most of the owners of steam vessels and builders of iron vessels in this country did not feel warranted in adopting the use of steel plate in the construction of vessels, mainly from the cause that this metal had not in the past given the best results in its use for other purposes. The manufacturers of steel in this country were at the time most persistent in their assurances that they could produce a uniform grade of steel suited to the wants of shipbuilding, and in quantities to meet all the demands of the constructors in this country at the time. There is no question but that they were one of the main factors in the rapid development of our steel shipbuilding. With them it was a question of an increase of business for their large plants. In 1882 there were eight steel mills in this country that were able to produce rolled steel plate, each of 20 tons and over per day, composed of the Otis Iron and Steel Company, of Cleveland, Ohio, the largest producer; Singer, Nimick & Co., Hussey, Howe & Co., Park Brothers & Co., Schoenberger & Co., Juniata Iron and Steel Works, Spang Steel and Iron Company, and Linden Steel Company, of Pittsburg, Pa., and the Bay State Steel Mills, of Boston, Mass. By 1884 there had developed among the constructors and builders more confidence in the use of steel, though at first there were several merchant vessels, built but partly of steel. More all-steel vessels began to take form after 1886. The adoption by the Navy Department of the use of steel in the construc-



THE SOUND STEAMER "PURITAN."



THE FIRST ALL-STEEL RIVER STEAMER "CHATTAHOOCHEE."

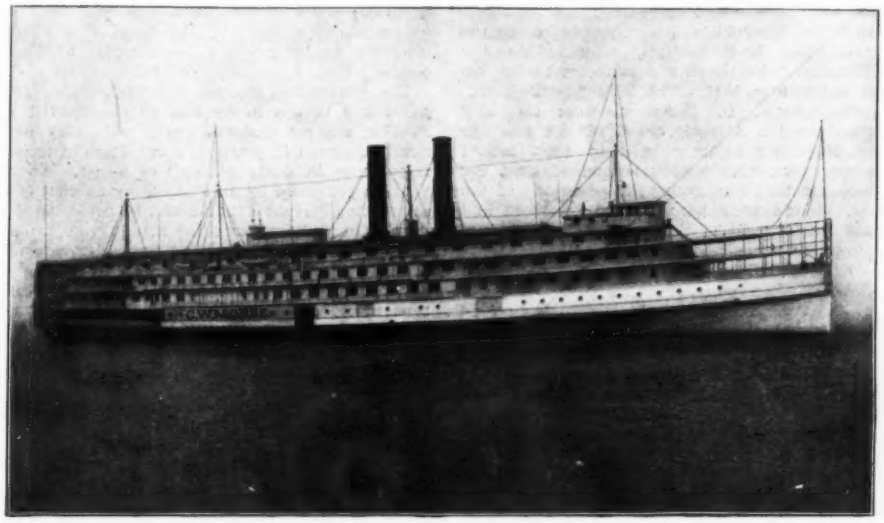
Was intended for service in Gulf of Mexico. Boiler was a flue-return tubular type.

The opening of the experimental stage of steel in shipbuilding in this country may be said to date from the time of the permanent adoption of steel for shipbuilding in Great Britain. The vessels constructed were small in comparison to those built of steel in the United States a few years later, but it showed a confidence on the part of the builders in the use of steel

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

tion of the first vessels for the new navy had its effect in the use of steel in the building of new vessels for the merchant service.

There was not at first any merchant vessel in this country built wholly of steel, as that metal at the time was to the designer and builder too much of an unknown quantity to be used wholly in the construction



THE HUDSON RIVER STEAMER "C. W. MORSE."

of a vessel. The steel manufacturers having every confidence in the mild steel plate they could make for structural work of shipbuilding and bridgebuilding, as equal to the better grade of iron plate for similar purposes, soon had its effect in inducing some of the builders to use the steel plating for some of the vessels. It was not eagerly sought by consumers from its first introduction for all-steel vessels, but had to work its way into favor on its merit, from the designers and owners of vessels, and this took three or four years.

About the earliest of these part-steel steam vessels was the "Alaskan," built by the Delaware River Iron Shipbuilding and Engine Works for the Oregon Railway and Navigation Company, launched August 7, 1883. It was the shell plating only that was of steel in this vessel, all other plates, shapes, etc., being of iron. The "Olympian," a mate to the "Alaskan," having steel plating also, was completed for the same company but a few weeks after the "Alaskan," by Harlan & Hollingsworth Company. The "Chicago," "Atlanta," "Boston," and the "Dolphin," then building at Chester, Pa., were all-steel even to the rivets. The "Atlanta" was launched October 9, 1884, the "Boston" on December 4, 1884, the "Chicago" December 5, 1884, and the "Dolphin" April 12, 1885.

At the time these Pacific coast vessels were completed the Harlan & Hollingsworth Company had two large steam yachts under construction; the "Electra" having angles, bulb T beams, and shell plating of steel, the balance of the hull structure being of iron. This vessel was launched in April, 1884. The "Nourmahal" was almost wholly of steel, but very little iron being used in building the hull. This vessel was launched in May, 1884. They also built the "City of Palatka" for Florida waters, partly of steel, that was finished late in 1884. There were a few ferryboats, tugs, and comparatively small steam yachts, their hulls being in whole or in part of steel, built during the same year at the yards on the Delaware River and on the Hudson River. The large steam yacht "Alva," built entirely of steel, by Harlan & Hollingsworth Company, was launched October 14, 1886.

The steel hull was now recognized as being the advanced type of vessel. At first, it was not adopted for another reason, on account of the increased cost of steel plate over iron plate, but in a very few years the price of ship steel was reduced to so near the price of iron plate that it was adopted more generally, and at once on the northern lakes, where a large demand was being made for increased tonnage.

Of the early *all-steel* vessels for the merchant service built on the Atlantic coast, may be named the "Puritan," of the Fall River line, launched July 25, 1888; "Iroquois," of the Clyde line, in 1888; "Leona," of the Mallory line; "Yumuri" and "Orizaba," of Ward line, in 1889; the "Yucatan," for the Ward line, and the "Seguranca," for the New York and Brazil line, in 1890; "El Rio," for Southern Pacific Company, in 1892.

There were 43 steam vessels built on the Atlantic coast, in whole or in part of steel in the construction of the hull, from 1884 to 1890, consisting of coastwise steamships, steam yachts, and ferryboats, of an aggregate of 31,183 net tons. The largest of these vessels was the "Seguranca." There were equally as many built in same time of iron entirely.

The first steel vessels of later years built in Great Britain were constructed in 1878 of mild steel:

	Iron. Tons.	Steel. Tons.
1878	.....	4,470
1880	459,994	35,373
1885	303,825	162,641
1890	42,069	957,894
1895	7,789	862,595
1897	9,206	763,766
1901	.....	1,438,700

The Lighthouse Board had built in 1887 at Baltimore, Md., by H. A. Ramsay & Co., the twin-screw tender "Zizania," having a steel hull complete. This vessel was the second steam vessel having *two sternposts* and two rudder-posts. The first one was built by J. H. Dialogue at Camden, N. J., for service at Galveston, Texas, a few years before. The motive power of the "Zizania" was a fore-and-aft compound engine operating each screw. On account of the contractors becoming financially involved before the vessel was launched, the board was compelled to finish the vessel themselves. They also had built the same year two steel-hull light vessels at Marcus Hook, Pa., by Woodbridge & Hutton. These vessels were built on the "combination" system, having a complete steel hull, the outside of the hull plating having a layer of tarred hair felt, this being covered with yellow pine planking fastened with iron bolts, and the hull then sheathed over the planking with hard-rolled zinc sheathing.

NORTHWESTERN LAKES.

The development of iron shipbuilding on the northwestern lakes was of very gradual growth, for it is found that in twenty years after the building of the "Merchant" in 1862, there were but 49 steam vessels built of iron for the lake service. The demand for larger vessels was met by the limited depth of water in parts of the Detroit River and St. Clair River. The "Cuba" and the "Java," built in 1872, were about the largest vessels on the lakes for over five years. The competition with the railroads, and the supply of oak timber for building wooden vessels running short at this period, were other causes that brought about in a few years the more general adoption of the iron-hull vessel. This change in favor of iron-hull vessels had no more than been fully recognized by the builders and vessel owners on the lakes, than the Navy Department decided to adopt the use of steel in the construction of the new vessels for the navy. This brought before the marine interests of the lakes another radical change in the material for construction, just at a time when they had proposed a marked advance in the building of their vessels. Having the raw material for the making of steel, in the shape of the ore and the coal at their own doors, and the steel rolling mills so close at hand, they very soon adapted themselves to the change, and it was but a few years before they were building more steel-hull vessels on the lakes than were under construction on the Atlantic coast. They were now making up lost time.

There were causes for this apparent backwardness on the part of the vessel owners on the Atlantic coast, in adopting the use of steel to a larger extent at first. We must remember that the lines of the coastwise steamers, as well as those on the rivers along the coast, had been for about ten years before the opening of the steel era laying aside the wooden-hull vessels, and building new vessels having iron hulls, so that when the subject of steel for construction began to be agitated, there was a large percentage of the new vessels on the coast of iron. On the lakes it was different. They had but very few iron-hull vessels; probably not more than fifteen in the passenger and freight business in 1882.

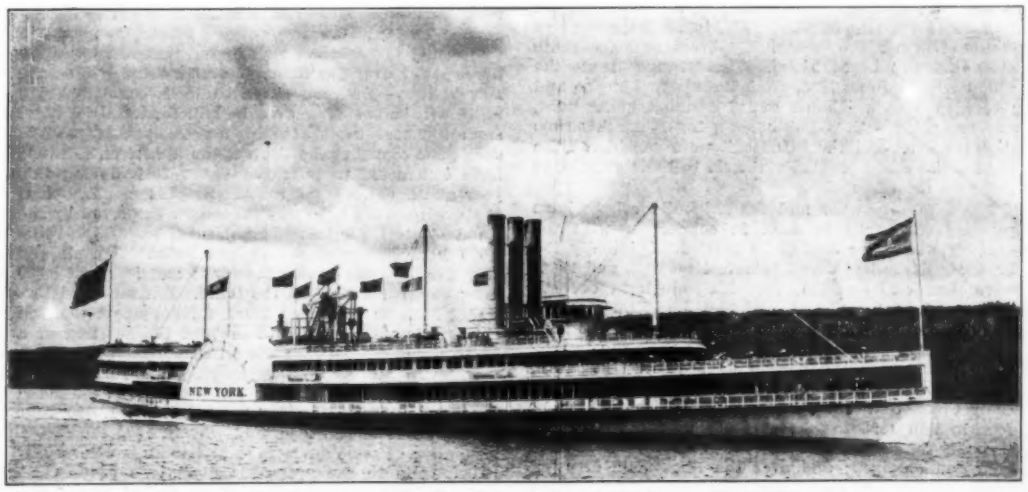
The large demand that was now made for material of steel in construction of steam vessels, bridge building, and steel framing for large buildings, was such that the owners of the steel mills had prior to this time become interested in the opening of new mines of ore in the Lake Superior mining region, and steamship companies were formed by those in interest, who had new vessels built on the lakes for the transportation of their own raw material. This brought about a boom in shipbuilding in 1886 of steel vessels that has continued to almost the present day, with but little change, except enlarged size of vessel. At the same time the Navy Department entered upon a plan for the further enlargement of the fleet of naval vessels, that called for the production of hundreds of tons a year of steel for their construction, and this increased the demand for lake tonnage to supply the raw material for the making of the finished steel. What increased the demand a few years later still further, was the successful operation of the armor-plate mills, in producing the armor for the United States naval vessels. So in the course of a few years the use of iron was turned aside, and steel adopted in its place, in the building of vessels on the lakes. It is thus seen there was more than one cause for its rapid growth on the lakes. They have also made marked advances in the methods of construction, and it was but a few years before the builders on the lakes were in the front rank in their methods of construction. As the shipbuilding plants were mostly all new in 1886, they had the advantage of the equipment of their plants with all the improved and up-to-date power and labor-saving machines, that gave them much advantage for the time over the older and longer established builders on the coast.

The use of mild steel for the hulls of the modern type of steam vessels on the northern lakes was first made use of in two vessels built at the Wyandotte Shipbuilding Company's yard. These were the "Albany" and the "Syracuse," propellers of 1,900 tons each, built for the Western Transit Company, of Buffalo, N. Y., and were *entirely of steel*. The "Albany" was completed in September, and the "Syracuse" in October, 1884. The former was sunk in collision with the "Philadelphia" on November 7, 1893. These vessels had fore-and-aft compound engines built by the Detroit Dry Dock and Engine Works. The same builders launched in April, 1885, the twin-screw propeller "Mascotte," of 112 x 22 x 8 feet, having part steel hull and two high-pressure engines.

The propeller "William Chisholm," of 1,500 tons, was launched by the Globe Iron Works Company August 7, 1884, having iron and steel plating and steel angles in the hull, and fitted with a compound engine.

The "Tioga," of 2,080 tons, was completed in July, 1885, at Buffalo, N. Y., by the Union Dry Dock Company, having the larger part of the hull constructed of steel, and having steeple compound engines, for the Union Steamboat Company.

The first *all-steel* hull built by the Globe Iron Works Company was the "Spokane," of 2,350 tons, for the



THE HUDSON RIVER STEAMBOAT "NEW YORK."

Wilson Transit Company, having fore-and-aft compound engines, and launched in July, 1886.

The first *all-steel* hull by the Union Dry Dock Company was the "Susquehanna," of 2,780 tons, having three-cylinder compound engine, for the Erie and Western Transportation Company, launched September 4, and completed in November, 1886. This vessel was designed as a larger carrier, and to be more economical in operation than the "Onoko," that was hardly fulfilled in all particulars when in service.

The next year the Globe Iron Works built the *all-*

steel propeller "Ira H. Owens," of 1,750 tons, for the Owens line, having compound engines.

To this time all the steel-hull vessels on the lakes had been equipped with compound engines, but the triple-expansion engine had been built for merchant vessels on the Atlantic coast for a few years past, and their economy in operation over the compound engine had been generally recognized. The operation of many of their steam vessels on the northern lakes with high-pressure steam, or as non-condensing engines, had been the practice for many years, so the change to the compound engine, and then the triple-expansion engine, did not involve such a radical change in the working steam pressure that it had in the steam vessels on the Atlantic coast, where the low-pressure condensing engine was the general type of marine engine, even in most of the propeller engines. The first engine of the triple-expansion type on the lakes was in a steam yacht named "Peerless," built by the William Cramp Shipbuilding Company, and sold to parties on the lakes in 1885 or 1886. The first of that type of engine built on the lakes was placed in the wooden-hull steamer "Roumania," built in 1887 at West Bay City, Mich., and the engine by S. F. Hodge & Co., of Detroit, Mich., and the same year one was placed in the iron-hull steamer "Cambria," built by the Globe Iron Works Company. It was not until the next year that the modern type of steam vessel, having the steel hull and the triple-expansion engine, was adopted, when the "Carona" and the "E. P. Wilbur" were built by the Globe Iron Works Company, and the six vessels for the Northern Steamship Company, by the same company, and the "Scranton" by the Cleveland Shipbuilding Company. This was the opening stage of the boom in shipbuilding on the lakes.

There were built in 1891, 29 iron and steel steam vessels having an average of 1,671 net tons.

In 1893, 25 vessels, average 1,990 net tons.

In 1896, 25 vessels, average 2,544 net tons.

In 1900, 26 vessels, average 3,700 net tons.

In 1902, 33 steel vessels, average 3,265 net tons.

In 1904 there was a total gross tonnage built on the lakes of steam vessels of 152,773 tons.

In 1898 there were 216 iron and steel steam vessels, having a total gross tonnage of 407,908 tons.

In 1904 there were on the northern lakes 421 iron and steel steam vessels of a gross tonnage of 1,088,960 tons, and 30 iron and steel sailing vessels of a gross tonnage of 100,633 tons.

The periods of the changes to the advanced types of steam vessels may be stated:

The " Philadelphia," built by David Bell in 1868, of 1,463 tons; the "Onoko," by Globe Iron Works Company in 1882, of 2,164 tons; the "Globe," by the Globe Iron Works Company in 1894, of 2,995 tons; the "Victory," by the Chicago Shipbuilding Company in 1895, of 3,774 tons; the "North West," as a passenger steamer, by Globe Iron Works Company in 1894, of 4,244 tons; the "S. F. B. Morse," by F. W. Wheeler & Co. at West Bay City, Mich., in 1898, of 4,936 tons; the "Douglass Houghton," by Globe Iron Works in 1899, of 5,332 tons; and "James C. Wallace" in 1905, by American Shipbuilding Company, of 6,684 tons.

There was a breaking away from the old form of vessel when the Union Steamboat Company had constructed in 1887 at Buffalo, N. Y., two steel-hull vessels of 1900 tons each, named "Owego" and "Chemung." They were modeled after our coastwise steamers, having finer lines than the more modern lake vessels, intended for higher speed, and were fitted with triple-expansion engines built in New York. While they made better time than the usual type of lake vessel, they were more expensive to operate, and smaller carriers of freight for their dimensions. The "Owego" is credited with having made the trip from Buffalo to Chicago in May, 1889, in 58 hours, and in the next month the "Chemung" over the same route made the trip in 54 hours. The "Owego" made the round trip in June, 1890, from Buffalo to Chicago and return in 5 days 5 hours and 3 minutes, going light, and returning with 85,000 bushels corn. At this time the "Harlem" and the "Hudson" were considered the most modern and profitable vessels to their owners, of those on the lakes.

The lake shipowner and the shipbuilder both have peculiar conditions to meet in connection with the draft of water and load to be carried. Originally the St. Clair River had seven principal mouths, and these were obstructed by sandy deposits, reducing the depth of water from 2 to 6 feet, and the Lime Kiln crossing in the Detroit River could not be depended upon for more than 13 feet of water. So here were the restrictions that bound the designer for years until 1870, when there was a depth in the canal of 13 feet at St. Clair Flats, that was further increased in 1873 to 16 feet, and in 1893 to 18 feet depth over the bars and through the canal, and at the present time 21 feet has been obtained; and over the Lime Kiln crossing the same depth of water has been found. Taking the depth of water, kind of freight that is mainly transported, and they have designed a vessel of a peculiar but thoroughly efficient type. The vessels have a moderate draft of water, fair speed, and economy of operation, with unrivaled facilities for loading and unloading their cargoes at their docks.

The most novel production of late years in steel shipbuilding in this country has been the whalebacks of the northern lakes, constructed by the American Steel Barge Company at West Superior, Wis. They were the invention of Alex. McDougall. Their first steam vessel was the "Colgate Hoyt," of 276 x 36 x 22 feet, that was completed in the fall of 1890. The "Joseph L. Colby," of about the same size, and having a fore-and-aft compound engine of 28 and 50 inches by 42 inches stroke, and operated by 120 pounds steam, was completed in November, 1890, and sent to the Atlantic coast. In the following month the "C. W. Wetmore" was sent from the lakes with 95,000 bushels of grain through the canal, and arrived at Quebec July 5, 1891, and shortly after left for Liverpool. She was reported at New York on August 14, and shortly after cleared for the Pacific coast, and passed San Francisco in 76 days from Philadelphia, Pa. She was lost on the Pacific coast. The "E. B. Bartlett," a duplicate of the "C. W. Wetmore," but having a triple-expansion engine, was finished in 1891. The "Colby," "Bartlett," "Wetmore," and "A. D. Thomson" were the only steamers sent to the Atlantic coast. There was one passenger whaleback steamer built in 1893, named "Christopher Columbus," having accommodations for 5,000 passengers that ran from Chicago to one of the lake ports. There have been sixteen steamers and twenty-four barges built of this type on the northern lakes in fourteen years.

(To be continued.)

THE DISTRIBUTION OF POWER.*

By W. E. AYRTON.

PROBABLY, like myself, you have heard vague comparisons made between the power of the Victoria and the Niagara falls. Now, what is the true comparison? The flow at Niagara varies at different times of the year from 62 to 104 million gallons per minute. At the Victoria Falls the flow can be one-twelfth of the smaller number—for it is so now and some authorities, well acquainted with the spot, say that at the end of another three months the flow will only be half of even that. The mean available drop at Niagara is about 160 feet; at the Victoria Falls 380 feet. Hence, while the minimum Niagara flow represents about 3,000,000 horse-power, the present Victoria flow represents about 580,000 horse-power, or only about one-fifth of the preceding. Further, if those who predict the flow of the Zambesi sinking to something like two and a half million gallons per minute in November are true prophets, the Victoria Falls will then only give out about 300,000 horse-power, or, say, one-tenth of the minimum that Niagara produces. In all that precedes I have taken the full power of the direct drop in each case—that is, I have assumed in each case the intake to be close to the main drop, and I have deducted nothing for inefficiency of machinery.

Now, how exactly does the efficiency in the electric transmission of power depend on (1) the pressure, (2) the power transmitted, (3) the length of the transmission line, (4) the resistance of the conductors composing it?

The very simple approximate formula connects these quantities:

$$\left\{\begin{array}{l}\text{Percentage}\\ \text{loss of power}\\ \text{on the road.}\end{array}\right\} = \frac{\text{Horse power transmitted}}{\text{3 (thousands of volts)}^2} \times \text{miles} \times \left\{\begin{array}{l}\text{Resistance per}\\ \text{mile of all the con-}\\ \text{ductors in parallel.}\end{array}\right.$$

This formula tells us that as long as the electric pressure is limited to some 10,000 or 11,000 volts, a pressure boldly used as early as 1897 by the Rand Central Electric Works and at the Moodie mines, near Barberton, but the one that is still the maximum sanctioned in Great Britain, it will not be possible, even with a pair of conductors of good copper, and each as thick as three-quarters of an inch in diameter, to transmit more than about 6,000 horse-power, or to transmit that power more than about ten miles, without the loss on the road exceeding ten per cent. The actual efficiency will, of course, be less than ninety per cent, since there will also be losses in the machinery at each end of the transmission system. Not only have various successful 60,000-volt transmission schemes been carried out, but the Kern River Power Company, in California, is constructing one for transmitting 4,020 horse-power over 110 miles at 67,500 volts. When the new railway—Brakpan to Witbank—is completed, 110 miles will be twenty more than will separate the Rand from the coal fields at Witbank—fields that produce such good coal that the Central South African railways have contracted to purchase 84,000 tons during this year at 6s. ($1.44) per ton at the pit's mouth. Now, if six wires were used like those now employed by the Rand Central Electric Works, then, at 67,500 volts, 9,000 horse-power might be put in at Witbank and only five per cent lost on the road; that is, about 8,950 horse-power delivered on the Rand. But the insulators would have to be placed much farther apart than on the existing Rand posts to prevent the starting of a brush discharge between the wires.

You will now grasp why in 1895, ten years ago, it was a bold and pioneering policy to equip the Rand Central Works for 10,000 volts and to use 13,000 volts during times of full load, and why in 1905 the recommendation of some advisers to distribute power at only 10,000 volts to the proposed substations of the contemplated fifty-seven miles of electrified railways—Springs to Randfontein—is most retrograde of those advisers to the railway. In 1879 a firm of electrical contractors, well known then and equally well known now, told me that they had been asked to tender for the construction of an electric transmission system to convey a comparative small amount of power ten miles. But since they considered that they could not possibly hope to deliver more than half, while, in practice, they feared that they would only succeed in delivering much less, the proposal had to be ranked with the exploits of Gulliver and Baron Munchausen, and so even that firm declined to tender. To-day, twenty-six years later, electric power is, from an engineering and from a business point of view, being successfully transmitted 232 miles.

Next I come to a very important question, and one that merits far more consideration than it has yet received. There are two kinds of electric current—direct current and alternating current. Now which kind of electric current should be used for the distribution of power over long distances? Practically, every electrical engineer will at once reply: alternating, of course. Well, I am going to preach heresy.

The alternating current has undoubtedly the great advantage that a motor can be constructed with no rubbing electric contacts, every wire may be permanently soldered in position, a condition of considerable importance in dusty places like mines. Another advantage possessed by an alternating current is that an alternating-current dynamo can be constructed to produce a large horse-power at a high voltage; and further, this alternating voltage can be transformed into a still higher one without the use of moving machinery. Contrasted with this, no single large direct-current machine has ever been constructed to generate more than about 3,500 volts, and no means is known for efficiently converting a direct-current voltage into a higher or a lower one without the use of moving machinery.

So far, then, my case seems weak. The advantages of using great electric pressures we have seen. Are there any disadvantages? This is a disadvantage—the risk of piercing the insulation. See how thick the insulating material has to be on cables, how far apart the conductors have to be placed, even when the cable is intended for only 10,000 volts. But does this consideration supply any argument for, or against, the use of one kind of current rather than the other? Small current and high pressure must be used for the economical transmission of power over long distances, whether the current be alternating or direct, I agree, but, I submit that, while from the point of view of economic transmission, 60,000 volts alternating means exactly the same as 60,000 volts direct, from the point of breakdown of the insulation, 60,000 volts alternating is as bad as 85,000 volts direct, indeed, may be worse than 100,000 volts direct. For an alternating current consists of waves like the waves of the sea. In a storm the waves may be running mountains high, and yet the average depth of the sea remains the same as in a calm. The mean electric pressure may not be very large, and yet the crests of the waves may be so high, and the troughs so low, that its strength can not stand the electric tossing.

But there are other disadvantages in the use of alternating current. One of them is the increased drop of pressure in an inductive circuit when supplied from an alternating source of supply instead of with direct current. This self-inductive effect, as it is called, is small, if the going and return conductors be straight, short and near together. But, if the distance over which the power is to be transmitted be long, the wires obviously can not be short, and if, to obtain economy, high electric pressure be used, the wires cannot be put very near together, since that would lead to a brush discharge through the air from one conductor to the other, producing leakage.

But that is not the whole indictment against the use of alternating current for long-distance transmission. Leakage from wire to wire can be rendered small, but still if the current be alternating, it always flows along the wires, even if all the apparatus at the distant end be entirely disconnected from them. The very first thing that struck Ferranti, the Brunel of electricity, when he commenced transmitting power with alternating current at 10,000 volts pressure from Deptford to London was that the current flowing into the system at Deptford was as large during the daytime, when practically no lamps were turned on in London, as during the evening, when many were glowing. And, in the case of the 150 miles transmission at 50,000 volts, by the Bay Counties Power Company, in California, it was found that to charge even the aerial lines as a condenser required forty amperes, so that the current flowing into the system remained practically unchanged when the useful load was decreased from several thousand horse-power down to nought.

Now, this is the very opposite of the effect we previously noticed, for in that case it was the alternating pressure that failed to send the current into the transmission system. Surely, then, the one effect is a correction of the other. That is so, and I will give you a practical illustration.

[The lecturer then showed experiments illustrating the neutralizing effects of capacity and inductance, and showed how resonance is established in electric circuits.]

Much damage has been done to electric cables used for the distribution of power by the unexpected high pressures produced by resonance in alternate-current circuits. A cable may have been tested at twice or thrice the working pressure and passed as satisfactory. But if there is a liability of a pressure being applied, which, as you see, may in somewhat extreme cases be twenty or thirty times the working pressure, what avails it, there being a factor of safety of two or three—disaster must follow.

Now, with direct current for long-distance transmission, there is no question about the electric pressure at the top and bottom of a wave being much greater than the mean pressure, no question about self-induction reducing the current—no objection, therefore, to putting the conductors as far apart as the risk of

* Abstract of a lecture delivered at the meeting of the British Association, Johannesburg.

brush discharge may necessitate—no question about capacity current, no resonance troubles, etc.

You are thinking, if the arguments were sound, the direct-current system would have been already employed for long-distance transmission. Well, but it has. Power up to 3,000 horse-power has been transmitted with direct current, at 14,000 volts, from Combe Garot to Le Locle and La Chaud de Fonds, round a circuit thirty-two miles long, 4,600 horse-power has been transmitted with direct current at 23,000 volts, thirty-five miles from St. Maurice to Lausanne, and a transmission system for 6,000 horse-power at 60,000 volts, over 114 miles from Moutiers to Lyons, is in course of construction. Another advantage that is possessed by all these examples of direct-current transmission carried out by M. Thury, is that it is the current that is kept constant, and the electric pressure that is automatically raised, when the demand for power is increased, whereas, with the ordinary alternate-current system, it is the pressure at the lamp end that they aim at keeping constant and the current that varies automatically with the demand for power.

Now, it is far more easy to maintain the constancy of the current flowing round a long circuit than to prevent the bobbing up and down of the electric pressure at the distant end of a long transmission line, and that irritating dancing of the lights, which Johannesburg is so familiar with, would be particularly difficult to avoid if the transmission line were long and the electric pressures at its two ends differed by some thousands of volts. Constant current has also its well-known disadvantages, but these would not come into play if the constant current were not taken into houses, mines, etc., but used to drive motor-generators in substations, the dynamo portion of the motor-generator being of any type desired.

The pioneering development that American boldness, enterprise, initiative, and originality have brought about in the electric distribution of power, combined with the extraordinary commercial success that it has won on both sides of the Atlantic, have made people ask, "Is such an industrial revolution in store for South Africa?" At first sight one is inclined to answer, "No." This country is dotted with coal fields—coal fields blacken the map, and the produce of some of them is reported to be nearly equal to the best Welsh coal in quality. When, on the one hand, one hears that good coal is brought from Witbank and delivered to the mines on the Rand at 13s. ($3.25) a ton, and that even this price will be lowered on the completion of the new railway from Witbank to Brakpan, one feels that long-distance electric distribution has not much chance—indeed, a proposal to burn slack coal at Vereeniging, only thirty-three miles from Johannesburg, and electrically distribute the power on the Rand, fell through. On the other hand, when one finds that at the Wankei coal fields themselves large coal costs 15s. ($3.75) a ton at the pit's mouth, and that Salisbury pays 36s. 5d. ($9.10), Umtail 43s. 6d. ($10.87), and Kimberly 67s. ($16.75) per ton, one feels that electric distribution in this country possesses possibilities.

South Wales has many coal mines—cheap slack coal lies heaped at the pit's mouth. Let me put this question to you: "If an electric supply distributing company were to start in South Wales to obtain their electric energy, not from water-falls, mark you, but from coal brought to their generating stations from coal mines, would you anticipate, I ask, that such a company would obtain customers for their electric energy at the coal mines themselves?" "No, emphatically no," you would reply, for that would be taking coals to Newcastle with a vengeance. And yet, within four years since that South Wales company was merely applying to Parliament for an act to enable it to establish a distribution of power system, fourteen of the largest colliery companies and thirty of the mines are taking power at about one cent per horse-power-hour, the demand three months ago having reached 13,000 horse-power, and rapidly increasing.

That the North-Eastern Railway, and such a large number of manufactories along the Tyne, should, as seen from that other diagram, take power from the Tyneside Electric Power Supply Company—which also has been but four years in existence—was perhaps to be expected, but that coal mines should obtain power by the burning of the product of distant collieries resembles at first sight the method of earning a living attributed to a certain village—viz., by taking in one another's washing. But this result is but an example of the subdivision of labor. At a coal mine, getting coal, and at a gold mine, getting gold, is the business; and at both, especially in the early days of sinking the mine, it should pay better to buy electric energy from an outside source than to generate the current on the spot.

Niagara sends 24,000 horse-power to Buffalo, thirty miles away, and sells it at 1.4 cents per horse-power-hour to an eight-hour user there—a price which is not cheaper than the total cost of generating a horse-power-hour at Buffalo with a large ste m engine. But tapping electric wires to obtain any amount of power that may be needed, and just at the time that it is required, is far more convenient than erecting steam engines and getting up steam, and certainly cheaper in the early days of sinking a mine.

It has been objected that the total steam-power curve of all the gold mines on the Rand shows the same sort of falling off during the hours 4 to 7 A. M., and 5 to 8 P. M., and, therefore, that apart from using larger and more economical engines, and from diminishing the cost of superintendence for the energy sent out, there would be no saving by supplying many mines with electric power from a common generating station. But if there be a railway in the neighborhood, largely used by workmen, the slack hours of the mines will be the busy hours on the railway. Hence, if that railway be run electrically from the same generating station, the load curve will be flattened and much improved.

On the Rand, however, there is an indisposition apparently to utilize distribution of power on a large scale. The labor conditions in this country are certainly peculiar. Mr. Denny, in his book on "Deep Level Mines of the Rand and Their Future Development," expresses this opinion: "It has, however, been fairly conclusively proved that in average conditions hand labor is both speedier and cheaper than machine drilling." Contrary to American and Australian experience, it may be true that in this country white men and machinery may be dearer and slower than black machinery and man rolled into one. But it makes one uncomfortable, even unhappy, to think it possible, for it means that the muscular machine is more valuable than the inventor's brain.

Another objection felt by mine owners here to investing much capital in machinery is the somewhat uncertain character of their business, and a third against a mine depending for a supply of power on an electric current coming from a distance is the climatic conditions. South Africa has various unique big things, but it has not a monopoly of big atmospheric disturbances, and these disturbances do not prevent electrical distribution of power schemes being pushed forward by leaps and bounds in the other three quarters of the world. During my short stay in this country I have been giving this matter much consideration. Without stopping this evening to discuss the subject in detail, I may mention that, after the admirable work of Mr. Wilms, Mr. Spengel, Mr. Heather and others here, on the improvement of lightning arresters for electric transmission lines, I think I also see my way to putting a nail into the coffin of these bugbear lightning troubles.

But, while advocating electric transmission of power, I should not start by constructing a transmission line from the Victoria Falls to Johannesburg. And I say that, not because I am of opinion that it could not be made to work, nor that, if direct current were used, it could not be relied on to give as satisfactory results as, or even better results than, some shorter existing ones on the alternate-current system, but because it does not appear to me that along the route there is at present sufficient demand for power to justify as large an expenditure of capital as would be compatible with a transmission line 586 miles long as the crow flies, and which would be no less than 745 miles long if made along a railway through Pietersburg and Gwanda, should that missing stretch of railway between these two places ever be constructed.

Those who hold the opposite view will doubtless urge that when the Cataract Construction Company, of Niagara, acquired in 1890 the right to use 100,000 horse-power, and a further right to subsequently use another 100,000 horse-power, it required an extraordinary belief in the future of electrical engineering to expect that 200,000 horse-power could ever be distributed at a price that could compete with large local steam engines. And now what is the state of things? The total electrical horse-power that could be sent out from these various Niagara power-houses, when completed will approach 700,000 horse-power, and represents about thirty per cent of the water going over the falls at the time of minimum flow.

Now what has caused this vast development in the distribution of power; what is the secret of this extraordinary success? It is that in the immediate neighborhood of the falls there have grown up works which take some 60,000 horse-power, works which not only want cheap power, but power in an electric form for electro-chemical processes, and need it in an undiminished amount day and night, weekday and Sunday.

Now, what is the prospect of such a steady load growing up locally within, say, three miles of your falls? Even on the spot it is difficult to obtain trustworthy information; by some it is said that one condition of the contract for the construction of the railway, which is being pushed forward to the copper, lead and zinc fields at Broken Hill, 400 miles to the northeast, is that 100,000 tons of the ore must be sent to Beira yearly for ten years. If true, then that ore will not be available for reduction at the falls.

There is a convenient spot for a power station near the water at the end of the second gorge—all the Niagara power stations are on the top of the falls with the exception of that of the Ontario Power Company—and it is the latter method of construction that would be the most suitable to follow at a Victoria power station.

A BRIEF HISTORY OF ELASTICS.

THE theory of elasticity is virtually a creation of the nineteenth century. Antedating Thomas Young, who in 1807 gave to the subject the useful conception of a modulus, and who seems to have definitely recognized the shear, there were merely the experimental contribution of Galileo (1638), Hooke (1660), Mariotte (1680), the elastic curve of J. Bernoulli (1705), the elementary treatment of vibrating bars of Euler and Bernoulli (1742), and an attempted analysis of flexure and torsion by Coulomb (1776).

The establishment of a theory of elasticity on broad lines begins almost at a bound with Navier (1821), reasoning from a molecular hypothesis to the equation of elastic displacement and of elastic potential energy (1822-1827); yet this startling advance was destined to be soon discredited, in the light of the brilliant generalizations of Cauchy (1827). To him we owe the six component stresses and the six component strains, the stress quadric and the strain quadric, the reduction of the components to three principal stresses and three principal strains, the ellipsoids and other of the indispensable conceptions of the present day. Cauchy reached his equations both by the molecular hypothesis and by an analysis of the oblique stress across an interface—methods which predicate fifteen constants of elasticity in the most general case, reducing to but one in the case of isotropy. Contemporaneous with Cauchy's results are certain independent researches by Lamé and Clapeyron (1828) and by Poisson (1829).

Another independent and fundamental method in elastics was introduced by Green (1837), who took as his point of departure the potential energy of a conservative system in connection with the Lagrangean principle of virtual displacements. This method, which has been fruitful in the hands of Kelvin (1856), of Kirchhoff (1876), of Neumann (1885) leads to equations with twenty-one constants for the æolotropic medium reducing to two in the simplest case.

The wave motion in an isotropic medium was first deduced by Poisson in 1828, showing the occurrence of longitudinal and transverse waves of different velocities; the general problem of wave motion in æolotropic media, though treated by Green (1842), was attacked with requisite power by Blanchet (1840-1842) and by Christoffel (1877).

Poisson also treated the case of radial vibrations of a sphere (1828), a problem which, without this restriction, awaited the solutions of Jaerisch (1879) and of Lamb (1882). The theory of the free vibrations of solids, however, is a generalization due to Clebsch (1857-58, "Vorlesungen," 1862).

Elasticity received a final phenomenal advance through the long continued labors of de St. Venant (1839-55), which in the course of his editions of the work of Moigno, of Navier (1863), and of Clebsch (1864), effectually overhauled the whole subject. He was the first adequately to assert the fundamental importance of the shear. The profound researches of de St. Venant on the torsion of prisms and on the flexure of prisms appeared in their complete form in 1855 and 1856. In both cases the right sections of the stressed solids are shown to be curved and the curvature is succinctly specified; in the former Coulomb's inadequate torsion formula is superseded and in the latter flexural stress is reduced to a transverse force and a couple. But these mere statements convey no impression of the magnitude of the work.

Among other notable creations with a special bearing on the theory of elasticity there is the invention and application of curvilinear co-ordinates by Lamé (1852); the reciprocal theorem of Betti (1872), applied by Cerruti (1882) to solids with a plane boundary—problems to which Lamé and Clapeyron (1828) and Boussinesq (1879-85) contributed by other methods; the case of the strained sphere studied by Lamé (1854) and others; Kirchhoff's flexed plate (1850); Rayleigh's treatment of the oscillations of systems of finite freedom (1873); the thermo-elastic equations of Duhamel (1838), of F. Neumann (1841), of Kelvin (1878); Kelvin's analogy of the torsion of prisms with the supposed rotation of an incompressible fluid within (1878); his splendid investigations (1863) of the dynamics of elastic spheroids and the geophysical applications to which they were put.

Finally, the battle royal of the molecular school following Navier, Poisson, Cauchy, and championed by de St. Venant, with the disciples of Green headed by Kelvin and Kirchhoff—the struggle of the fifteen constants with the twenty-one constants, in other words—seems to have temporarily subsided with a victory for the latter through the researches of Voigt (1887-89).

MEASUREMENT OF CURRENTS BY THE QUADRANT ELECTROMETER.—For some cases it is advisable to measure small currents by the electrometer. O. M. Stewart considers the case where the current flowing into a conductor connected with one pair of quadrants is measured by determining the velocity of the needle, as is usual in radio-activity work. Treating the capacity as a variable, the author shows that after the velocity has become constant, the effective capacity becomes constant and has then the value given by J. J. Thomson. The ratio of the effective capacity to the capacity when the needle does not move can be obtained from the ratio of the deflection when the quadrants are connected to a certain potential to the deflection when the quadrants had only been connected a very short time. It is found that the maximum sensibility for current work does not coincide with the maximum sensibility for steady deflections. When the potential of the needle is changed until the effective capacity is twice the capacity when at zero and not allowed to move, the electrometer will be the most sensitive. This, however, is true only when the potential of the needle is below the potential giving maximum sensibility for ordinary deflections. It is worth consideration when the capacity connected to the electrometer is small compared to that of the electrometer itself. The equations deduced for the motion of the needle show that the deflection reached in a definite time after the earth connection is broken is in all cases proportional to the current. It is not necessary in this method to wait until the velocity has become uniform. It is, however, necessary to eliminate the disturbance sometimes caused by the breaking of the earth connection.—O. M. Stewart, Physical Review, July, 1905.

TELLURIC CURRENTS.

AN interesting communication was recently made by M. Guarini to the Belgian Astronomical Society upon telluric currents, their origin, direction, their disadvantages, and their possible utilization. As their name indicates, telluric currents are terrestrial electric ones. They must not be understood to be currents that originate in the earth, but rather currents that traverse the latter, since their origin is, in most cases, external.

As to their origin, there is no end to theories, which

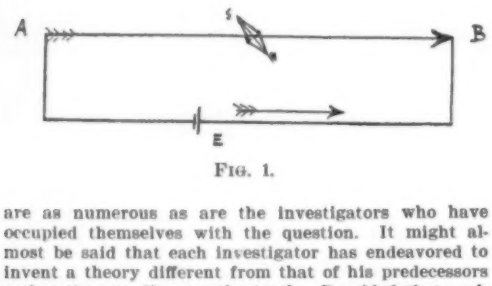


FIG. 1.

are as numerous as are the investigators who have occupied themselves with the question. It might almost be said that each investigator has endeavored to invent a theory different from that of his predecessors rather than to discover the truth. Provided that such theory is not in flagrant contradiction to the laws of science and is based upon experiments that are more or less convincing, it is at once proclaimed as the true one, and is so regarded until another one comes to receive the same consideration.

Some attribute telluric currents to the effects of wind, and others to those of rain, snow, and hail, as well as to sun, eclipses, chemical reactions of the earth, thermo-electric phenomena, etc. All such explanations, according to M. Guarini, are radically wrong or are at least in contradiction to the facts demonstrated.

M. Guarini, who admits that he has never demonstrated nor offered a hypothesis to explain telluric currents, has endeavored to make a step toward reconciling all the opinions that have been expressed.

The most complete and conclusive researches have been made in Germany by the department of post offices and telegraphs, and in France by M. Blavier. It results from these experiments that in ordinary weather, when there is no special atmospheric manifestation, telluric currents have a very determinate direction over the entire earth. This direction is determined in the following manner: Two telegraph lines are installed and two points at the same potential are sought. This is easy, considering that the difference of potential between two points of the earth is proportional to their distances. Now, it is merely necessary to join the two points in order to obtain an equipotential line, the perpendicular of which indicates the direction of the telluric current. The experiments of M. Blavier show that the telluric currents proceed from northwest to southeast, thus making with the geographical meridian an angle of about 70 degrees, and, with the magnetic meridian, one of about 56 degrees. This direction, however, undergoes slight, but continual variations. It is just this constancy of the telluric currents that caused M. Guarini to say that none of the explanations proposed is either complete or adequate, since each is based upon intermittent phenomena, and an intermittent cause cannot produce a constant effect.

The researches of the investigators mentioned above, as well as of others too numerous to mention, have shown that there is such a resemblance between the curves of the telluric currents and those of magnetism, i.e., of the magnetic declination and horizontal intensity, that it was very natural to ask if it was not the telluric current that produced the well-known deviation of the magnetized needle. Ampere thought that the deviation of the needle was not due to a central terrestrial magnet, but rather to telluric currents, and that the latter were directed from east to west, while in reality they go from west to east. This direction, moreover, is indispensable in order that the magnetized needle shall point toward the North Pole, by virtue of the law of Faraday and of Ampere himself.

It would be very easy, according to M. Guarini, to

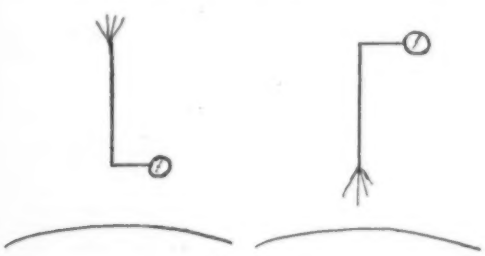


FIG. 2.

verify the matter, since, if it is the telluric current that causes the deviation of the needle at a given point of the earth, it would suffice to abolish the cause in order to do away with the effect. Let us suppose, then (Fig. 1), a telluric current that proceeds from *A* to *B* and causes a deviation of the magnetized needle, *C*, placed near a directing magnet, *D*, the influence of which is less than that of the telluric current. If it is the latter that causes the needle to deviate, it will suffice to neutralize its effects by a current that is equal, but of contrary direction, near a current-source, *E*, in order that the directing magnet may act and cause the needle to deviate parallel with the magnet.

M. Guarini afterward touched upon the origin of the constant telluric currents. Are such currents induced by the atmosphere, or are they induced in it? The Italian meteorologist Palmieri solved the question by a logical reasoning and an interesting experiment. If the electricity of the earth were not induced, it would be impossible to have, as is often observed, great differences of potential in neighboring regions, such as Naples and Vesuvius. Such difference may be understood, on the contrary, if we grant that the currents are

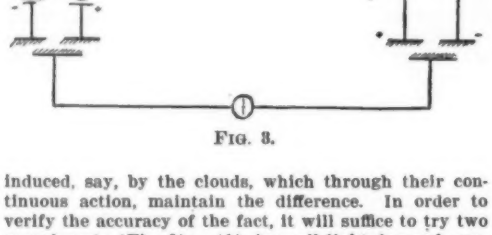


FIG. 3.

induced, say, by the clouds, which through their continuous action, maintain the difference. In order to verify the accuracy of the fact, it will suffice to try two experiments (Fig. 2): (1) A small lightning rod, connected with an electroscope, is placed with its points upward, and the electroscope is seen to indicate a positive charge; (2) the same lightning rod arrangement being placed with its points downward, the electroscope indicates nothing. If the atmospheric current were induced by the earth, the latter ought to have acted still more upon the lightning rod than upon the atmosphere, and the electroscope should have shown a negative charge. Consequently, the inductive electricity is positive and resides in the atmosphere.

As for the energy of the atmospheric electricity, M. Guarini mentioned numerous theories, such as that of Palmieri, who explains it as due to the evaporation of water. In his opinion, it is not only the current of the earth, but also that of the atmosphere that is induced. Through the revolution of the earth around the sun, there is developed in the atmosphere a current of a direction contrary to that of the rotary motion. This current, induced in the atmosphere, develops in its turn in the earth, a current of a direction contrary to that of its own. It must be remarked that this latter fact is in accordance with those observed, that is to say, the earth revolves in the direction of the telluric current—from west to east.

In M. Guarini's opinion, then, the sun and the earth with its atmosphere constitute a gigantic dynamo in which the sun is the stationary inductor and the earth the movable armature with two superposed windings. In our epoch of centralization of power, M. Guarini's idea of having recourse to a terrestrial electric works in which occurs a cosmic phenomenon that produces the necessary power, although pretty risky, is not so trivial as might be thought at first sight. In support of his hypothesis, M. Guarini recalls the Foucault disk, and the experiments of Werner, Siemens, Quet, and Gaietel, who have proved that the solar radiations induce positive electricity in the bodies exposed and dissipate the negative electricity that they contain. We know that this phenomenon is confirmed by the recent observation made by Marconi, to wit, that the energy necessary for wireless telegraphy is much greater when the sun is shining, because the latter induces in the receiving antennæ a charge that destroys the negative semi-period of the waves. M. Guarini sees here a new proof of the revolution of the earth. He remarked that at a preceding meeting he had established the fact that there is a concordance between the curves of the variation of temperature and those of magnetic declination. Since, on the other hand, a concordance has been found between the curve of magnetic declination and that of telluric currents, M. Guarini holds that there consequently also exists a concordance between the curves of variation of temperature and those of telluric currents. He explains the matter by the fact that if the sky is cloudy, the mean temperature descends, and the clouds and fog partially protect the earth against the indirect electric action of the sun.

As for the abrupt variations, particularly the magnetic storms of telegraphers, the cause of these seems to reside in the phenomena to which is generally at-

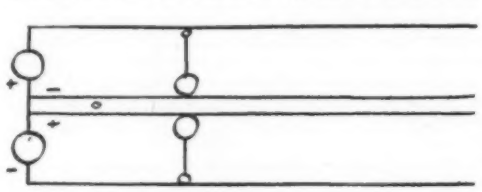


FIG. 4.

tributed the production of the telluric currents, i.e., wind, rain, etc. If, in fact, we change the difference of potential between two ground-plates, the intensity of the current will be modified. Disturbing curves, moreover, are not wanting. The wind produces a friction upon the earth and electrifies it. It produces variations of potential at points of the earth's crust, and, consequently, modifications in the intensity of the current. Upon the whole, we have here a static machine of the Armstrong kind that produces electricity by projecting vapor upon a conductor in the form of a comb. On the other hand, when it hails, rains, or snows, the earth, from being negative, as it ordinarily is, sometimes becomes positive. As before, the variations of potential of the ground-plates produce variations in the intensity of the telluric current.

How is this change of pole of terrestrial electricity to be explained? From Palmieri's experiments, it results that rain-drops, hail-stones, flakes of snow, etc., become charged in the atmosphere with electricity of a polarity contrary to that of the medium in which they exist. Upon approaching the earth, they induce therein a charge of a polarity contrary to their own, that is to say, positive. This charge destroys the negative one of the earth. The latter is then positively electrified. Clouds, storms, auroræ boreales, etc., act in the same way, produce variations of potential at the ground-plates and, consequently, variations in the intensity of the telluric currents. In addition to telluric currents of constant direction, there are others of variable direction that must be distinguished from the disturbing currents by one of the preceding causes. It has been stated above that the telluric current is at right angles with the line that joins two points at the same potential. If these two points happen to be raised to a sufficient difference of potential, a flow of current will occur from one to the other and the direction of such current will be at right angles with that of the constant telluric current.

From natural disturbances, M. Guarini passed to industrial ones, which do not seem to him as if they ought to be so much apprehended by meteorologists. The installation of electric street railways has frequently given rise to disputes with observatories, although the dispersion in the earth is rather slight owing to the great conductivity of the return rails. At present, an endeavor is making to utilize the earth as a return conductor. M. Guarini recalled this apropos of the St. Maurice-Lausanne experiments. Unfortunately, however, such use gives rise to great disturbances in telegraph and telephone circuits. M. Guarini has endeavored to prevent these, and his experiments have been successfully repeated by M. Thury. The system (Fig. 3) consists in employing two dynamos of half the power instead of one with full power and of grounding the terminal of opposite polarity of each. As the common charges communicated to the ground are equal and of opposite polarity, they annul one another. A galvanometer placed in a neighboring circuit with ground-plates very close to those of the transmission of energy shows no current. In order to prevent the disturbances due to street railways, M. Thury has devised a three-wire distribution (Fig. 4), in which the rails constitute the neutral conductor. The cars are provided with two motors and two trolleys. As the current intensities of the two motors in service are equal, the disturbances are null. M. Guarini thinks that the telluric currents are advantageous to agriculture because they electrolyze the salts contained in the ground and render them assimilable by plants, and because they hasten the germination and vitality of plants, and the osmotic exchanges, etc. They are useful to the navigator and explorer because they direct the magnetic needle. Unfortunately their inconstancy produces disturbances in the compass and, consequently, accidents. If the direction upon the magnetic needle is not certain, said M. Guarini, the best thing to do would be to get rid of these currents by giving the earth a sufficient charge by means of an alternating current without influence upon the compass.

We might also think of utilizing them. Did not M. Figueras, operating in the Canary Islands, draw from the atmosphere a current of 550 volts by means of which he ran a 25-horse-power motor? His process is a secret one, but is probably based upon the reversibility of static machines. This would be a famous resource. Elihu Thomson has calculated that between the earth and the upper strata of the atmosphere there must be a difference of potential of several million volts, and, on the other hand, the magnetism of certain ores of iron shows that they have been influenced by an average current of 6,000 amperes.

In order to utilize telluric currents, it would merely require, according to M. Guarini, a motor of very slight resistance as compared with that of the earth, which is almost null, a short and coarse conductor, and ground-plates as perfect as possible, so that the total resistance of the circuit shall be practically of little moment as compared with that of the earth. The telluric current would then divide itself into nearly equal parts between the earth and the desired circuit. The part of the current traversing the latter would be sufficient for practical utilization. This would be electricity at home, individual, and gratuitous, or nearly so.

M. Guarini concluded by dwelling upon the importance of the study of telluric currents to the meteorologist, agriculturist, and electrician.

In the case of root diseases caused by parasites in the soil or other unfavorable soil conditions, the development of resistant strains or varieties is often the only method practicable. Much has been accomplished in this direction. For example, varieties of grapes have been bred resistant to the California vine disease, which has annually destroyed the industry in several sections of southern California. The phylloxera-resistant quality of our native grapes has been made use of in breeding resistance into the tenderer European varieties, and our native varieties have also been used directly as stocks on which to graft the tender European sorts. This procedure has saved the grape industry of Europe, and is being used to a large extent now in California to guard against phylloxera.

CATALYSIS.

By A. RIGAUT.

A GREAT many chemical combinations and decompositions are determined, or accelerated, apparently, by the mere contact of certain substances, which are called catalyzers. The name catalysis was first applied to these contact reactions by Berzelius, in 1829. These phenomena have always aroused lively curiosity among investigators, and the interest which attaches to them has been increased in recent years by the catalytic manufacture of sulphuric acid from gaseous sulphurous acid, or sulphur dioxide, and air, meeting in presence of metallic platinum or of sesquioxide of iron.

The earliest known catalytic agent is platinum in

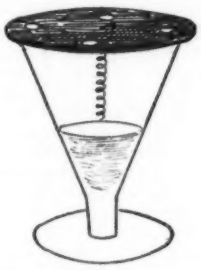


FIG. 1.—A FLAMELESS LAMP. ALCOHOL IS BURNT BY CONTACT WITH PLATINUM.

the form of foil or wire, but the action attains a maximum when the metal is in the state of platinum black, or of spongy platinum, resulting from the decomposition of the double chloride of platinum and ammonium. A platinum wire, once heated, remains incandescent in a mixture of air and alcohol vapor. The flameless lamp invented by Davy in 1821 is based on this phenomenon (Fig. 1). Under these conditions the alcohol burns at a comparatively low temperature. If methyl, or wood alcohol, is employed, the product of combustion is formic aldehyde or formaline, which is now used so extensively as a disinfectant (Fig. 2).

Spongy platinum, platinum black, and colloidal solution of this metal effect the combination of hydrogen and oxygen. This is the principle of Döbereiner's lamp, invented in 1827 and once very popular, and of the self-lighting gas burners of recent introduction.

Alcohol, in contact with air and platinum black, is oxidized to acetic acid. It has been proposed to adopt this process in the commercial manufacture of vinegar.

When a mixture of ammonia and oxygen is caused to flow over slightly-heated spongy platinum, nitric acid is formed. Conversely, a mixture of nitric acid vapor and hydrogen produces ammonia.

Under the same conditions sulphur dioxide (sulphurous acid) and oxygen give rise to sulphuric anhydride (anhydrous sulphuric acid). (Fig. 3.)

This is the principle of the manufacture of sulphuric acid by the contact process, which has assumed such industrial importance. This catalytic action of platinum can be destroyed by the presence of various substances, including sulphureted hydrogen, carbon monoxide, and arsenic. The platinum also "ages," or loses its catalyzing power, with continued use.

The catalytic action of platinum may also effect decomposition, of peroxide of hydrogen, for example. Colloidal platinum, obtained by volatilizing platinum under water by means of the electric arc, decomposes peroxide of hydrogen, even when the solution contains only 1 milligramme of platinum in 350 liters. (1/50,000 of a grain to the pint, or one part in 350,000,000.)

Many other metals may act as catalyzing agents. Among these are nickel, cobalt, iron, and copper, as obtained in a very finely divided state, by the reduction of their oxides by hydrogen. Palladium causes

FIG. 2.—A FORMOGEN CATALYTIC LAMP, IN WHICH METHYL ALCOHOL IS OXIDIZED AND FORMALDEHYDE PRODUCED.

oxygen and hydrogen to combine slowly, without explosion. MM. Sabatier and Senderens have utilized the catalytic effect of nickel in producing synthetically the saturated hydrocarbons of petroleum by combining hydrogen with ethylene and benzine at 300 deg. C. Carbonic acid, treated in the same way, yields marsh gas.

In presence of nickel, carbon monoxide is decomposed into carbon and carbonic acid at 350 deg. C., and acetylene is resolved into its elements in the cold.

It should be noted that most substances which act by contact are in a very finely-divided state. Platinum black, when freshly formed in water, is so fine that it remains in suspension and passes through filter paper. The diameter of the particles has been determined to be about two millionths of a millimeter. It follows from this that the aggregate surface of all the particles in a gramme of platinum black is equal to 50 square meters (250,000 square feet to the pound). In the colloidal substances which, as we shall see, act as catalyzers, the state of division is very much finer than this.

Concerning the mechanism of catalysis, many hypotheses have been formed. In the case of hydrogenation, we may admit the formation of a very unstable and easily-oxidized hydride of the metal, which serves as an intermediary in the reaction. This is Sabatier's opinion, and it is supported by the ease and rapidity with which Moissan's metallic hydrides are decomposed and oxidized. On this chemical theory catalysis is explained by an intermediate and transitory reaction.

It is well known that finely-divided substances, as well as platinum, palladium, and iron in the form of thin foil, have the power of absorbing gases, and that this condensation, or "occlusion," of the gas is accompanied by the disengagement of a quantity of heat sufficient to raise the mass to the temperature of ignition, if the action takes place rapidly. In other words, the gases are ionized by the heat, that is to say, they acquire electric charges and become resolved into ions, whose opposite polarities explain their chemical activity and their resultant combination. The ionization of gases by heat is a fact demonstrated by experiment. Many other ingenious electro-chemical theories of catalysis have been proposed.*

Catalytic action is not confined to metals. Pumice stone heated to 100 deg. C. effects the explosive combination of mixed oxygen and sulphureted hydrogen. At a lower temperature, or with an excess of sulphureted hydrogen, sulphur is precipitated.

Bone black and wood charcoal also cause certain reactions, including the combination, without explosion, of chlorine and hydrogen at 100 deg. C., and com-

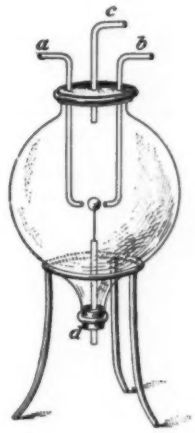


FIG. 3.—CATALYTIC PRODUCTION OF SULPHURIC ANHYDRIDE.

d, Support for platinum sponge; *a*, inlet for sulphurous gas; *b*, inlet for oxygen.

bination of chlorine with sulphur dioxide and with carbon monoxide at various temperatures.

In the manufacture of sulphuric acid by the contact process, sesquioxide of iron may be substituted for platinum for the purpose of effecting, at 450 deg. C., the combination of sulphur dioxide and atmospheric oxygen (Fig. 4). Now, sesquioxide of iron, or iron rust, is an oxidizer, as is shown by the slow-corroding action of rust spots on linen. The sulphur dioxide, therefore, is oxidized by the sesquioxide of iron, forming ferrous sulphate, which is immediately oxidized and decomposed by the air, producing sulphuric anhydride and regenerating sesquioxide of iron.

The same reaction between sulphur dioxide and oxygen, induced by passing the mixed gases over common salt and a little oxide of iron, yields sodium sulphate and hydrochloric acid gas. This method is employed in the Hargreaves and other manufacturing processes.

The contact action of oxide of iron also enables us to obtain sulphur from sulphureted hydrogen derived from the residuum of the soda process. Sulphureted hydrogen and oxide of iron first produce water and sulphide of iron, and the latter then takes up oxygen, reproducing oxide of iron and yielding free sulphur. This is the well-known process of Claus.

The oxides of manganese and copper, as well as oxide of iron, decompose potassium chlorate at a temperature below fusion. In this case the occurrence of an intermediate reaction has been proven. When oxide of manganese is employed, potassium permanganate is formed. This is shown by the pink coloration produced when a trace of manganese dioxide is added to fused potassium chlorate.

In the same manner a solution of potassium hypochlorite is decomposed, with evolution of oxygen, when a salt of cobalt is added.

Now, it is known that the first product of the action of chlorine upon potassium hydrate is potassium hypochlorite, which is converted successively into chlorate, into perchlorate, and into oxygen and chloride. (Fig. 5.) As Prof. Ostwald, the eminent Leipzig chemist, has observed, we thus pass from a system of abundant free chemical energy through a series of systems, each of which has less free energy, and consequently greater stability, than its predecessor. The

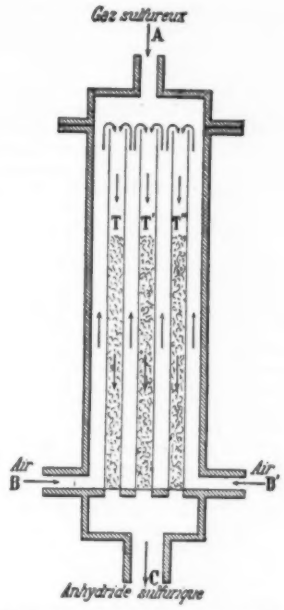


FIG. 4.—PREPARATION OF SULPHURIC ACID BY THE CONTACT PROCESS.

T, T', T'' are electrolytic tubes.

effect of the catalyzer is to mask the intermediate reactions which lead to the final and most stable system. In fact, when chlorine acts upon potassium hydrate in presence of a salt of cobalt, the disengagement of oxygen and the formation of potassium chloride take place immediately. The same thing occurs in the electrolysis of a solution of potassium chloride.

The salts of manganese are catalytic agents of remarkable power. When dissolved in water they are partially decomposed into free acid and manganese monoxide. The monoxide is very easily oxidized into the dioxide, which is an oxidizer and acts as such in the Leclanché galvanic cell. Therefore, a trace of a salt of manganese, added to an oxidizable substance, will cause the latter to be oxidized by the air. For example, a neutral solution of hydroquinone, which does not oxidize spontaneously when exposed to a current of air, blackens on the addition of a trace of a salt of manganese. M. G. Bertrand has shown that certain oxidizing diastases, for example, *lactase*, which occurs in the latex of the lac tree, owe their oxidizing properties to the presence of manganese acting by catalysis, like a sort of mineral ferment.

Iron plays an analogous catalytic rôle in the red blood corpuscles and in chlorophyl. The phenomena of vital chemistry depend upon this mechanism of reactions due to infinitesimal quantities of mineral substances contained in diastases.

Under certain conditions, water may be a catalytic, as well as a vital agent. It is now proven that absolutely dry mixtures of hydrogen and oxygen, hydrogen and chlorine, carbon monoxide and oxygen, do not combine, even at high temperatures. Metals are not affected by perfectly dry oxygen.

Now, water is an ionizer, and it resolves into their ions, more or less completely, salts dissolved in it. Some chemists attribute the catalytic action of water to this ionizing property.

It has been shown by experiment that the combus-

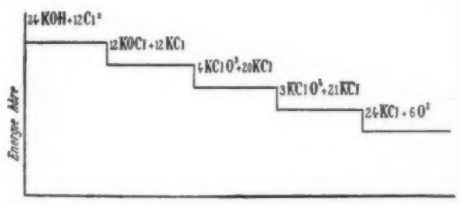


FIG. 5.—SUCCESSIVE ACTIONS WITH INCREASING LOSSES OF FREE ENERGY.

tion of hydrogen is accompanied by the formation of hydrogen dioxide, HOOH, which may be regarded as consisting of two ions OH, derived from two molecules of water H-OH. Hydrogen dioxide is thus an intermediate product in the combination of hydrogen and oxygen.

Fluorine, when absolutely dry, does not attack glass, but under the influence of a trace of moisture it acts upon the silica of the glass, producing oxygen and silicon fluoride. The fluorine, acting on the small quantity of water, produces traces of hydrofluoric acid, which attacks the glass, forming silicon fluoride and water. The latter, with the free fluorine, again forms hydrofluoric acid and oxygen, and the process is repeated indefinitely. An analogous phenomenon is the transformation of vitreous arsenious anhydride into

* Conroy, La Catalyse. Revue générale des Sciences, 1902. Simon, Conférence sur la Catalyse, Société chimique, 1903.

opaque anhydride, by solution and progressive crystallization. The crystallization of barley sugar takes place in a similar manner.

Hydrochloric, sulphuric, and other mineral acids accelerate the etherification of alcohols by weak acids by means of catalytic action due to the formation of intermediate ethers. They also facilitate the conversion of starch and other carbohydrates into fermentable substances, by hydrolysis.

The oxides of nitrogen are employed as catalyzers in the manufacture of sulphuric acid.

Another example of catalysis is presented by the production of chlorine by the Deacon process, in which hydrochloric acid is oxidized, at 400 deg. C., by air in presence of bricks impregnated with cuprous chloride.

We may mention also the manufacture of white lead, in which acetic acid serves as the intermediary and catalyzer.

The commercial production of phthalic acid, the raw material of artificial indigo manufacture, from naphthaline by oxidation is also due to a contact action.

Finally, a word should be said about colloids, such as silica, alumina, silver, gold, and oxide of iron, which can be brought to a state of division so fine that they remain indefinitely in suspension in pure water, but are coagulated by a trace of a solution of a crystallized salt. The colloid thus coagulated is quite insoluble and retains the most soluble salts imprisoned in its mass.

The diastases, also, are colloids. We have already seen that they act as catalyzers, and noted the important part which they appear to play in vegetable and animal life.

The exploration of this vast field of catalytic phenomena has barely been commenced. Independently of all theory, it has been discovered that the catalyzer acts chiefly by modifying the rapidity of the chemical reaction. With the aid of the new conceptions of matter bearing electrical charges, the study of these reactions may be expected to give us a complete mechanical theory of chemical combination.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from La Science au XXme Siècle.

THE STATURE OF MAN AT VARIOUS EPOCHS.*

By A. DASTRE.

AN idea which has gained popular credence, and still hazily lingers in many cultivated minds, is that man of the present day is descended from a handsomer, stronger, and more superb ancestral race. In the course of time, it is said, the powerful sap that nourished the mighty bodies of our ancestors has, little by little, become corrupted or exhausted, until debilitated, feeble, and nervous generations have succeeded the productive, rich-blooded, and exuberant generations of old.

Without going to such an extreme, some students, more positive and more scientific, think nothing more than that the human body has undergone a sort of evolution of decline, manifesting itself in a progressive diminution in size. These ideas, which appear in various forms, becoming more and more veiled, are nothing else than remnants of an ancient superstition, the belief in giants.

What is a giant? Does it exist? Can a race of giants exist? Has such a race existed? These are questions that in all times have excited a lively interest. The imagination of the ancients was fed on stories in which the heroes were either giants or else mere pygmies. Even to-day tales about giants enliven our infancy. The reality of their existence excites such universal curiosity that it should not be cause for wonder that it has given rise to interminable and fruitless discussions among savants.

Of all these writings—of these innumerable fabulous stories of combats between giants and gods, and the discussions about giants—nothing worthy of consideration remains. Recent works upon the subject are of more value. The problem now presents itself in a more practical aspect than it did to our predecessors. We have more records than they had; we are in a position to know whether man's size has varied in prehistoric and historic times, and whether there ever existed aggregations of colossal men meriting the appellation "race of giants." Since it is incontestable that individuals of gigantic size do appear from time to time, a systematic study of the subject should be undertaken and would yield invaluable results. The research begins by investigating the significance and reason for the existence of these monstrous beings, and ends by learning why they can not reproduce and perpetuate colossal creatures like themselves.

Two sciences, anthropology and medicine, control the study of the subject, and the progress of our knowledge in the matter is due to both of them. The present article will deal with the subject chiefly from the anthropological standpoint, more especially in the light thrown upon it by contemporaneous anthropological research. The part which medical science played in explaining the causes of aberrations from the normal size is sufficiently definite and limited to warrant separate examination without inconvenience to the student. A word or two about it here will, therefore, be enough.

Anthropologists have applied the rule and compass to the study of primitive man, and they have measured in whole and in part the remains of our ancestors that lived in the geologic ages, the humble hewers of stone from the Quaternary age up to the dawn of the present era. Popular fancy exaggerated their size immoderately, for anthropologists, through the implements of an exact science, have found that instead of being giants they were men of only mediocre height. Anthropologists have also unearthed skeletons of men that lived since the beginning of the historic period, and measurements here, too, have proved that the average height of man shows no tendency to diminish. Scientists, then, by careful methods of measurement have furnished evidence in favor of the truth that Jean Riolan tried to establish as early as the beginning of the seventeenth century, and which he clearly expresses in the title of one of his works published in 1618, "Discourse on the Height of Giants," in which it is shown that in all times, even the most ancient, the tallest men and the giants were no bigger than the giants of the present day.

To come back to the bearing of medical science upon the subject, it is medicine which has most recently thrown light upon the question of giants, and medicine maintains that to it belongs the study of giants in the present day, the rare few that now and then appear. Giants are men whose development instead of pursuing a normal course has undergone a morbid deviation, and whose nutrition has been perverted. They are dystrophic. Their great stature shows that one part has gained at the loss of another; it is a symptom of their inferiority in the struggle for existence. Their condition is not only a variation from the ordinary conditions of development—that is to say, they are "congenital monsters," the study of which belongs to the science of teratology—but it is a variation also from a state of health physiologically and normally sound; that is to say, they are diseased and fall within the domain of the pathologist. "Here, then," as E. Brissaud says, "you have your giants despoiled of their ancient and fabled prestige; mythology yields the place to pathology." Such is the new doctrine in its most categoric or most expressive form.

The imagination of all ancient peoples was haunted by the chimerical vision of a sort of superman, like ordinary man, but bigger and stronger. These beings of perfect proportion, but of colossal stature, were giants. The conception has remained firmly fixed in popular belief, and it has been so general and so deep rooted that the question must perforce arise whether it did not have some foundation in reality. *A priori*, one is tempted to see in it the recollection, magnified by tradition, of a colossal race that actually existed. All mythologies, in fact, contain legends of giants. Greek mythology represents huge beings, children of the earth, carrying on formidable conflicts against the gods who inhabit heaven. The details of the struggle are recounted in a thousand different ways; now, it is an army of giants who stand in battle array under the leadership of Alcyoneus and Porphyrion and await the attack of the inhabitants of Olympus, aided by the hero Hercules. Another time it is Otus and Ephialtes, who pile mountain upon mountain to scale heaven and throw burning rocks against it. But the wars which break out over and over again always end in the triumph of the king of the gods; and the giants doomed to inevitable defeat are struck by Jupiter's thunderbolts, crushed under the wheels of his chariot, and finally hurled into Tartarus.

Historians and critics who insist that all myths have a significance symbolic and natural at the same time have no trouble to explain this one. They find in it a reflection and personification of the subterranean forces in revolt against the laws of nature—the Greeks said Divine laws—which require and maintain the solidity and fixity of the earth. These irregular, tumultuous forces, volcanic eruptions, earthquakes, violent cataclysms, these agents of destruction proceeding from the bowels of the earth and loosed against the order of the world, that is, against the gods, all these are giants. It is a remarkable fact that while the poets in symbolizing these natural forces gave frightful descriptions of them, endowing them with multiple members, with horrible heads, and enormous mouths spitting flames, the Greek artists, on the contrary, always susceptible to actual forms, represented them simply with human faces and figures. For example, in a painting on a very ancient vase the giant Antæus is represented as thrown into a prostrate attitude by Hercules and seeking to touch the earth with his hands in order to draw fresh vigor from it. His body, though that of a man admirably proportioned, is nearly double that of Minerva, who strikes him with her lance, or that of Hercules, who draws a bow upon him. Moreover, the hugeness of the body is itself a rare and exceptional feature in the representations of the Greek artists, who quickly renounced this significant deformation, so that in ancient art giants would not have been distinguished from ordinary human beings if, after the archaic period, the custom had not arisen of terminating their lower limbs in the bodies of serpents. A beautiful cameo in the museum at Naples shows Jupiter crushing under the wheels of his chariot some serpent-footed giants whom he had already thrown to the ground with his thunderbolt.

Analogous legends have been transmitted to us by the historians of all the peoples of antiquity. Scholars have collected many references to giants in the Scriptures and in the writings of profane authors. Sometimes the huge beings form a whole people, or a tribe, or an ethnic group, though most frequently they appear in history as exceptional individuals. A list of references would be too long to be given here. It must suffice to mention a few sources of information, as Etudes biologiques sur les géans (Masson, 1904), by P. E. Launois and P. Roy. Buffon in his work on the natural history of man gives some information obtained from the Memoir of Lecat read in his day at the academy of Rouen. It is there recalled that the Greeks attributed to Orestes a height of 11½ feet, which Pliny consented to reduce to 7 cubits or 10½ feet. He also mentions the skeletons of Secondilla and of Pusio, preserved in the gardens of Sallust. These could not have measured less than 10 feet. In our time Prof. C. Taruffi, of Bologna, in his work (Milan, 1878) on gigantism—which he calls macrosomy—collected a vast number of records which show that the general belief has threaded history that modern man is the dwindled, degenerate offspring of ancestors of gigantic stature. From this point of view the isolated specimens of giants that appear at long intervals would be accidental repetitions of a vanished type, belated representatives of an extinct race.

This universal, deeply rooted prejudice rests upon evidence so manifold and so categoric that it might easily influence all but the scientifically equipped critic, and it is not until relatively recent times that the man of science himself has been in a position to discuss the evidence and cast doubt upon the belief. It may be of some value to recall that ideas upon the subject even in the nineteenth century were still sufficiently indeterminate for Silberman to feel justified in raising the question, in 1859, before the Academy of Sciences, as to whether the human body has varied in size within historic times. He answered the question in the negative. He affirmed that the stature of the Egyptians had not changed since the construction of the pyramids; but some uncertainty attaches to the calculations made by him for arriving at the height of the contemporaries of the king Cheops in order to compare their size with that of the present generation.

The same uncertainty does not characterize the methods of modern anthropometry. Only limited faith is placed in the evidence of historians, geographers, or voyagers, and none but scientific measurements can be relied upon. The stature of vanished populations is obtained directly by measuring their skeletons or parts of their skeletons, the relations of which to the whole have been established by previous study and careful research. No one has gone further than L. Manouvrier in determining precisely the relation, long ignored, that exists between the various parts of a skeleton. For the use of anthropologists he codified after a fashion the rules outlined of old by Orfila and revised by Topinard and E. Rollet in France, by Humphry and J. Beddoe in England, and by Langer and Toldt in Germany. He made a sort of chart for ready reckoning, by the aid of which, from the dimensions of the femur or the tibia, we can deduce the height and the size of the body itself. The degree of approximation of the results is known, the extent of the extreme aberrations, the causes of the aberrations, and all the conditions, in short, for reducing the aberrations to a minimum. In these means of investigation contemporaneous anthropology has weapons with which to attack the prejudices that have long existed in regard to the gigantic stature of our far-removed ancestors and in regard to the pretended diminution in size which the human figure has been progressively undergoing.

Errors and exaggerations such as these have been collected, transmitted, and propagated by historians of all times. The first expression that they received is incontestably to be found in the Bible. The Hebrew scriptures allude in various passages to enormous men—as, for example, the population found by the spies of Moses in the Promised Land. The prophet Amos compares these occupants of Canaan to oaks for strength and to cedars for height. The simile forcibly recalls almost the very words of the Poèmes Barbares, in which the hordes of primitive men are described as they issue from dark woods and limitless deserts:

"More massive than the cedar, taller than the pine."

In the Book of Kings the giant Goliath is said to have been 11 feet 4 inches tall; and Deuteronomy narrates that the iron bed of Og, the King of Bashan, was 9 cubits, or about 15 feet, long. All the Jews, however, did not entertain blind faith in the accuracy of these figures, and many of them questioned how gigantic races, so powerfully built, could have completely disappeared. The prince of scribes, Esdras, who edited the canonical books at the end of the Babylonian exile and freed them of errors that had crept into them, pleads the progressive debasement of the race. Succeeding generations grow smaller and smaller; and so the colossal statures of the first men have dwindled to frailer forms. The opinion of Esdras appears among all peoples and in all histories of later times. The Greeks expressed the same idea of physical decadence, of a falling away from the grand stature of personages in the heroic age. Homer and Hesiod lament the decline, and, later, Herodotus, Pausanias, and Philostrates speak of it in a similar strain. Plutarch finally goes so far as to liken the men of his time to infants in comparison with the ancients. Among the Romans the same conception is found. Recall the lines of Virgil when the laborer with his plow turns up the bones and arms of his ancestors: "He gazes astounded on the gigantic bones that start from their broken sepulchers." Pliny in his natural history expresses even more extreme ideas in this regard. He mentions the discovery in a mountain of Crete of a human skeleton 6 cubits long, or more than 20 meters.

The moderns have had the same notions concerning the diminution of man's size. The historians of the Norse lands in many a passage celebrated the huge stature of the ancient inhabitants of Scandinavia.

Belief in the former colossal height of man and his continued decline in size through the ages seemed to be verified by the discovery of huge bones in ancient tombs. Lecat mentions tombs in which were found bones of giants 15, 20, 30, and 32 feet tall. But in his day scholars were no longer dupes of such evidence

* Translated from Revue des Deux Mondes and published in the Smithsonian Annual Report.

It was known at the time—that is, in the second half of the eighteenth century—that the enormous bones were not those of human beings, but of large animals. In the opinion of Buffon they belonged to a horse or an elephant; for, he says, at one time warriors were buried with their war horses, and so, possibly, with their war elephants. But in less enlightened times, the bones were taken to be those of immense giants and were venerated as such. Sometimes they were exposed at cathedral doors. According to Langer, cited by Launois and Roy, one could see an exhibition of this nature under the porch of the chapel of the castle at Cracow as late as 1872. It was composed of a mastodon's bone, the skull of a rhinoceros, and one of the jawbones of a whale.

Of all these finds the most celebrated on account of the discussions to which it gave rise was made in 1613 near Romans, Dauphiné, by workmen engaged in digging sand. Near a building of brick they unearthed a skeleton 25 feet long. Now, it was pretended that a discovery of medallions bearing the image of Marius had been made in the neighborhood; and these two events sufficed as ground for the supposition that the bones were those of the giant Teutobochus, king of the Teutons, who had been conquered by Marius, near Aix, in 102 B. C., and had died soon after. Jean Riolan, physician and skillful anatomist, said that it was an imposture to attribute the bones to Teutobochus. Other men, like Guillemeau, royal surgeon, and Nicolas Habicot defended the theory, and a controversy rich in incident lasted five years. The belief, which even in the time of Buffon seemed to lack the marks of verisimilitude, was not finally dissipated until De Blainville, in May, 1835, declared to the Academy of Sciences that the bones attributed to Teutobochus were those of a mastodon identical with mastodons previously found in Ohio.

For lack of populations of real giants, that is, men whose enormous stature separated them by a sort of hiatus from the tallest men one ordinarily sees, modern explorers have brought to our knowledge two races of men who are very tall without being inordinately so. They are called pseudo-giants. The two groups, representing the type of the tallest men on the globe, are the Patagonians of America, and the Polynesians.

The Patagonians are especially interesting. Magellan was the first to see them, in 1519, on the strait called by his name, between Terra del Fuego and the American continent. Once during the five months of winter that he was forced to pass in this region, which he thought uninhabited, the Spaniards were visited by a native, come without doubt from some distance. He was gay, vigorous, confident, and he did not hesitate to go on board the vessel. In the written account of the voyage, the height of this savage is described as having been so great that the head of an average-sized man in the crew reached only to his waist. He was stout in proportion, his strength was considerable, and his appetite commensurate with his size. Having been well treated, he soon brought some of his companions of his own proportions. Magellan gave them the name of Patagonians.

If this description were to be taken absolutely literally, the Patagonians must have been about 8½ feet tall. Elsewhere, it is true, the author of the narrative ascribes to the natives only 7 feet 6 inches. It is interesting and instructive to note the variety of estimates made of their height by voyagers who have seen them. Magellan accords them 7½ feet; Commodore Byron 7 feet; the Dutchman Sebald de Noort 10 to 11 feet. Smaller size, however, is attributed to them by Commerson, traveling companion to M. de Bougainville and the Prince of Nassau. He says their height is not much greater than that of the average-sized Frenchman, usually from 5 feet 8 inches to 6 feet; none exceeded 6 feet 4 inches. This is far from being gigantic, as Commerson remarks, and he comes out very strongly against the fables and lies related concerning these pretended Titans. He is right. The Patagonians are men of great size, but they are by no means giants. Topinard, who forty years ago measured a fairly large number of their skeletons, assigns to them a height of 1.78 meters.

The general run of anthropologists admit the division of races or peoples into four groups, according to their average height. The first group is that of the "tall-bodied," ranging from the English (1.703 meters), the shortest among them, to the Tehuelches of Patagonia (1.781 meters), the tallest, and including the Scotch (1.710 meters), the Scandinavians (1.713 meters), the Negroes of Guinea (1.724 meters), and the Polynesians (1.762 meters). The second group is of those "above the average" (1.65 meters to 1.70 meters), which, beginning with the French (1.650 meters) at the bottom of the scale, comprises the Russians (1.660 meters), the Germans (1.677 meters), the Belgians (1.684 meters), and the Irish (1.697 meters). The size of the third group, that is, of those below the average, ranges from 1.65 meters downward to 1.60 meters, and includes, among others, the Hindoos (1.642 meters), the Chinese (1.63 meters), the Italians of southern Italy, and the Peruvians. The last group is that of the "short-bodied," which includes, among others, the Malays and the Lapps.

The Patagonians, then, are only tall men, but they "hold the record," which fact, however, has been disputed, first, in favor of a population on the Upper Nile, the Dikas; next in favor of the Polynesians, then the Scandinavians, and last, the Scotch.

To recapitulate: There actually exists, then, no population or ethnic group of giants. Specimens of giants do appear, but only in isolated, individual, and accidental cases. Since physicians at the present time liken gigantism to a malady, we may say (from now on borrowing their language) that this disease is nowhere endemic, that it manifests itself a little everywhere, but in sporadic cases under the influence of conditions yet to be determined.

So much for the question of gigantism in present times. But the question is not one of the present; it is the past that perplexes, and it is the past with which we are concerned.

As we have seen, it is in the past, in the long-distant past, in which tradition has placed the origin of a race of giants, who have subsequently undergone a process of progressive degradation. This thesis has been adopted by a fair number of writers more or less qualified to judge of the matter. Some of them, like Henrion in 1718, even ventured to draw up a table giving in positive figures the series of degradations undergone by the human stature in the course of time, from Adam, said to have been 123 feet (40 meters), Abraham, 27 feet (9 meters), and Hercules, 10 feet (about 3 meters), to Alexander the Great, 6½ feet (nearly 2 meters), and Cæsar, 5 feet (1.62 meters). These figures are so absolutely puerile and fantastic that they do not merit attention.

It is the task of anthropometry to try to estimate man's size in the various epochs of history as well as in prehistoric times and geologic ages. For this it is necessary to arrive at some sure method of calculating the real size of the living being from his skeleton, or from fragments of his skeleton, found in the deposits of the Tertiary or Quaternary periods or in the sepulchers of historic times. The establishment of such a method of mensuration has for many years occupied L. Manouvrier, and it constitutes one of his best titles to a scientific reputation. The basic work that he published on the subject appeared in 1892; and recently, in 1902, he crowned his efforts, as it were, by issuing a study "upon anthropometric relations and the principal proportions of the body" (sur les rapports anthropométriques et sur les principales proportions du corps). The memoir is of great interest to natural history in general. Parts of it are well worthy the attention of artists, painters, and sculptors, whose classical canons, perhaps a bit factitious, ought to be submitted to the control of the science of man as he really is.

The results of the investigations made by L. Manouvrier can be expressed in a word. They have proved that man's stature has not undergone any important regular variation during the hundreds of thousands of years that have rolled by since his first appearance upon the globe. So far as one can judge from the isolated specimens brought to light by excavations, the stature of man has undergone no appreciable change. In this regard civilized man is the same as primitive man.

The study of animals has led to similar conclusions. In general, the body of animals of a certain species or of a certain variety is not modified; or if it is modified, the change has causes by no means displaying the character of a chronologic evolution. Geoffroy Saint-Hilaire, in order to show that man's stature has not necessarily changed since geologic times, based his argument upon precisely this fact, that the body of a domesticated animal species is identical with that of the wild species.

The furthest removed ancestor of man seems to be the famous *Pithecanthropus erectus*. In the course of the years 1891 and 1892, as may be remembered, a physician in the Dutch army, Eugène Dubois, discovered near Trinil, on the island of Java, some bones of puzzling appearance and with characteristics intermediate between those of a man and those of an anthropoid ape. There, in a deposit undoubtedly of the Tertiary epoch, were a complete skull, a femur, and two molars.

Simple as were these remains, they nevertheless sufficed for assigning to its proper place and rank in the animal hierarchy the being from which they came. It belongs between the anthropoid ape, the gibbon, and man himself. The femur, whose form indicates adaptation to an erect posture, reveals man; the skull, whose capacity is too small for man but a little too large for an ape, reveals a superior anthropoid. The remains were in a state of fossilization corresponding to their antiquity and permitting them to be handled without danger of breaking them. They were exhibited throughout Europe and submitted to the examination of all competent anatomists—Krause, Waldeyer, Virchow, Luschan, Nehring, in Germany; Milne Edwards, E. Perrier, Filhol, in France; Cunningham and Turner, in England.

(To be continued.)

Vegetable growing as a specialty is more profitable near the larger cities. Cities ranging in size from 25,000 in population upward are the ones which should be considered in this connection. The reasons for this have already been briefly alluded to, but may again be referred to here. They are, chiefly, that vegetable growing must necessarily be specialized, and that there can be a demand for special crops in large communities only. Since the rapid extension of vegetable growing in the South and the better facilities afforded for the shipment of such crops as lettuce, cucumbers, etc., the field for the growth of vegetables under glass has been considerably restricted. There are still good opportunities here, however, and the larger the city the more chances there are for success. The grower in this case can sell his own crops, or he can sell them through a commission merchant or wholesale dealer in the city or cities to which his locality is tributar-

ENGINEERING NOTES.

Unfortunately, soft coal, our best fuel, is at the same time our dirtiest fuel both in the handling and in the burning. The smoke from most other fuels, while not suitable for the lungs of human beings, is, if carried to a sufficient height by a chimney, comparatively inoffensive, since it does not return to earth.

It is claimed by many that what we gain in the maintenance of the locomotive piston valve we lose through the leakage of the packing rings. No doubt, there are some leaks through the packing rings in the valve as they or the bushing become worn; but, on the other hand, how many times are slide valves slightly cut and allowed to run in this condition until they wear themselves smooth again? And while they are wearing themselves smooth the engineer will double the amount of oil to the valves and cylinders to prevent the lever from driving him out of the cab.

It may be said that the principal cause for loss in steam plants is the use of engines which are overloaded or unsuited to the conditions of work, under-sized, or badly-arranged steam and exhaust pipes, and the imperfect condition and poor operation of the boilers. In many plants exhaust steam, which might be utilized for heating, is wasted, and in others, where the exhaust steam is utilized for heating, power is wasted by excessive back pressure. The most economical use that exhaust steam can be put to is for heating, because all the heat units are made use of, but it should be done without back pressure on the engine, by means of a vacuum system to draw the steam and water through the heating pipes, otherwise there will be a loss both of fuel and power due to the engine working under imperfect conditions.

Experience shows that any of the standard types, horizontal return tubular, water-tube, or internally fired, if they are designed with proper proportions of heating and grate surface, give about the same evaporation per pound of coal, provided they are in good condition and clean both on the fire and water surfaces. While the externally fired boilers, either of the return tubular or water-tube type, are said to have some advantage in combustion on account of the heat of the brick furnace, they are subject to losses which are more serious, in the way of air leakage and radiation. Tests made at the Ohio State University, by Prof. Hitchcock, show that the brick-setting of boilers continues to absorb heat up to seventy-two hours after being started, and that the average waste of heat in brick furnaces is about eight and one-half per cent. The repairs and cost of keeping up brick furnaces is considerable, and as a result of deterioration there is more or less air leakage through the brickwork going on constantly. In this respect, the internally fired boiler has a great advantage over return tubular or water-tube boilers with brick furnaces, as it will be just as efficient after continued use as when first started.

We are indebted to English manufacturers to a great extent for the propagation of small engines for industrial purposes. This was a fertile field for investigation and experiment, which our makers, deeply immersed in the construction of powerful engines, have often failed sufficiently to notice. English engines, designed for the use of street gas, vie with each other in ingenuity in the arrangement of their parts in order to attain efficient and simple mechanical devices. The lift of the valves and their mode of operation are in general obtained by cam and lever movements with a definite movement giving a positive action. The governor itself is reduced to its most simple expression, since in the "hit-and-miss" arrangement its action consists merely in displacing to a slight extent a small piece which is normally interposed at the point of contact between the controlling lever and the stem or spindle of the gas valve in order to open it or to leave it closed, and which transmits the motion by which the valve is opened; when the piece is displaced the motion is no longer transmitted. Unfortunately, this type of governing is not compatible with the requirements of the working conditions of modern large engines.

There are three kinds of testing engineers—the unattached engineer, the consumer's engineer and the producer's engineer. At first there were apparently only two kinds of testing engineers—viz., the unattached and the consumer's. But it did not take long after consumers began to study and test materials and prepare specifications before the producers found it necessary to protect their interests and defend their materials by means of testing engineers in their own employ. It is perhaps hardly necessary to say that in this our analysis of the scope and field of the testing engineer we have not forgotten the various inspection bureaus and testing laboratories which are doing such excellent work in various parts of the country. These organizations, while perhaps not strictly covered by the definitions given in that they do not derive their continuous sustenance in such a way as the unattached testing engineers, nor in the same way as those who defend the interests of the consumer or the producer, yet in a certain sense these independent organizations do perform exactly the same functions as the three classes of testing engineers which we have described. Any one of them will make investigations either in the interests of a client or for the sake of the truth alone; any one of them will temporarily or continuously, if the retainer be sufficient, defend and care for the interests of a consumer, or will render a like service for a producer, provided of course that the interests of the two are not antagonistic at the same time.

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SCIENCE NOTES.

The physician of the future will see a growing preponderance of preventive medicine and the character of the profession in future years will be largely molded by the influence which this growth exerts. The activity of preventive medicine will be shown first in the case of public and domestic hygiene. The laws of good living are fairly well known to but few people.

It is difficult accurately to estimate the age of grape vines by the usual method of counting the rings, because the yearly growth is not distinctly marked. Some authors state that the vine equals, and even surpasses, the oak in point of age. In America we have been unable to ascertain the age that planted vines will attain, and the time that has elapsed since its discovery would not be sufficient had the experiment been begun when Columbus landed in 1492. Pliny mentions a vine 600 years old. Miller tells us some of the vineyards of Italy held good 300 years, and that vines 100 years old were accounted as young. Prof. Bosc states that some of the vines of Burgundy were 400 years old and more. It is more than likely that the advent of the phylloxera will have a tendency to shorten these age records in the case of the European and other non-resistant species. Doubtless there are native vines of much greater age.

A few years ago two German scientific men discovered that a minute drop of a mixture of oil and a salt of potash acted like a microscopic living thing in several ways. It would move about spontaneously, change its form, had a circulation in itself, would gather to itself particles of other matter in its neighborhood, and was sensitive to stimulus from the outside. It comported itself like a thing of life in all ways but one, it could not reproduce its like. The material itself was called artificial protoplasm. The work is still being investigated, both abroad and at home, with the hypothesis that if the proper chemical constituents can be found and added it will then be a real artificial living thing. As it already possesses four of the five distinguishing characteristics of a living thing, ingenuity and persistence will enable some one to find and endow it with the fifth. It will not be safe for one to predict that this can not be done, for it may be done to-morrow, and the twentieth century starts with a pretty problem considered as a physico-chemical problem, but the one who solves it, if it should be done, will have reason to be thankful he is not living in any preceding century, for his life would be made a burden to him, if he was not made a martyr.

In an age characterized by urban life and possessing sky-scrapers, tenement houses and other huge beehives, in which human beings aggregating vast numbers spend a large part of their lives, buildings require for their proper construction, lighting, heating, air supply, water supply, gas supply and drainage, the scientific services not only of architects, but of engineers, and such public buildings form one small section of the aid which modern *engineering science* is now everywhere rendering to public health science. The present has rightly been called an "age of engineering," and to no other science, excepting only medicine itself, is public health science to-day more indebted than to engineering science. Not only nearly the whole of London, but also Berlin and Hamburg, and a thousand lesser cities all over the civilized world, are now protected more or less perfectly from epidemics of typhoid fever, Asiatic cholera and other water-borne diseases by vast municipal filters, ingenious and scientific in design and costly in construction, the work of skillful and faithful engineers, and monuments, more precious, if less enduring, than brass, to the contributions of engineering science to public health science.

Next to the development of physiological knowledge which furnishes the basis of plant breeding, the growth of knowledge relating to plant nutrition has had the most important bearing on the art of agriculture. The germ of our modern theory first became evident about the beginning of the eighteenth century. Previous to that time it was believed that plants obtained all their food from the soil, although the elements and compounds constituting even soil foods were not known. The first step in advance was the demonstration of the fact that the leaves take part in the elaboration of food and that the larger part of the substance of plants is derived from the atmosphere. The lack of chemical and physiological knowledge at that period, however, made it impossible to proceed far in explaining these observations. It was not until nearly the end of the eighteenth century that definite proof was furnished that plants absorb and fix the carbon dioxid of the air and give off oxygen in the process, at the same time assimilating the elements of water and increasing in weight in a corresponding degree. This process was found to take place only in the light and only in the green parts of plants, and normally and copiously only when small quantities of certain mineral matters were absorbed by the plant through the roots. It was also observed, about this time, that all parts of a living plant absorb oxygen and give off carbon dioxid, just as animals do in respiration. The conclusion was reached, though founded on imperfect experiments, that plants can not make direct use of the nitrogen of the atmosphere. The great importance to agriculture of these observations was soon lost sight of, however, in a mass of unimportant matters and misinterpretations, and it was not until the appearance of Liebig's work in 1840, and especially until the investigations of Houssingault, between 1840 and 1850, were made, that the error was cleared away and the important facts clearly set forth.

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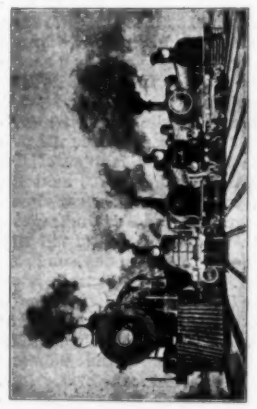

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